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SOME EFFECTS OF PILE AREA EFFLUENT WATER ON YOUNG CHINOOK SALMON AND STEELHEAD TROUT

A description of the experiments carried out at the Fish Laboratory between July 1, 1945 and July 5, 1946

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By Authority of N. F. Carroll, BORE 1-23-56

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August 31, 1946

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INTRODUCTION

The operation of the three Pile or 100 Areas requires the utilization of an appreciable amount of the water in the upper Columbia River which, under extreme conditions, may approach one per cent of the river flow. Such extreme conditions can exist during the winter months when the river is at a low stage if all three areas are operating at capacity. Much of the water which is utilized by the plants is altered both chemically and physically before being returned to the river and if present in sufficient volume might be expected to exert an effect on the fish and other life of the river. What these effects might be could not be predicted with certainty and considerable concern was felt for the valuable runs of salmon and other fish frequenting and spawning in the upper Columbia River.

In order to determine whether or not the more important species of fish might be harmed by the presence of the effluent water from the Pile Areas a laboratory was set up in the 100-F Area. This laboratory was so constructed that conditions which existed in the river could be duplicated as nearly as possible and that the effects of various concentrations of the area effluent water upon eggs and young fish could be studied. In the following pages a detailed description is given of the laboratory conditions and of the first series of experiments which were undertaken.

SUMMARY

Three separate experimental studies are covered in this report, namely a pilot study on chinook salmon fingerlings, an extensive study on steelhead trout fingerlings and a comprehensive study on chinook salmon eggs, fry and fingerlings. The test animals were held in wooden troughs similar to those used in most fish hatcheries and were subjected to various mixtures of the area effluent water and Columbia River water. The water mixtures or conditions in which the fish were held during the pilot experiment and the first part of the steelhead trout experiment were as follows:

Straight area effluent water partially cooled.
Straight area effluent water refrigerated.
One part refrigerated effluent water to 500 parts of river water.
One part effluent to 50 parts of river water.
One part effluent to 100 parts of river water.
One part effluent to 250 parts of river water.
One part effluent to 500 parts of river water.
One part effluent to 1000 parts of river water.
Straight river water.

During the latter part of the steelhead trout experiment and during the second chinook salmon experiment, dilutions of one part effluent to three parts river water and one part effluent to ten parts river water were substituted for the 1:500 dilution using refrigerated effluent and 1:100 dilution. The experimental conditions were run in duplicate except for the river water control which was run in quadruplicate.

Anticipated difficulties in the control of experimental conditions and fish diseases materialized but were largely eliminated during the pilot test and the early part of the trout studies. Inasmuch as these early studies

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were included chiefly as a test of equipment and conditions, their purpose was accomplished and in addition some evidence of the effect of the various concentrations of effluent water on the fingerling size salmonoids was obtained.

The pilot study demonstrated that undiluted area effluent water, whether only partially cooled or refrigerated to within the normal temperature range of salmon, was not suitable for the survival of chinook salmon fingerlings and was occasionally quickly lethal. Any possible effects which dilutions of the effluent water might have had were obscured by disease and mechanical difficulties.

The steelhead trout experiment showed much the same result. Extremely heavy mortalities occurred in the undiluted effluent water and, on occasion, in a dilution of one part effluent to three parts river water. The presence of some factor to which the trout were very sensitive, (probably "Calol"), killed many of the fish in the undiluted effluent water on August 31, 1945 and many more in the undiluted effluent and 1:3 dilution on October 11 and 16, 1945. The growth of the trout in both refrigerated and unrefrigerated effluent water was markedly retarded and growth in the 1:3 dilution was slowed for a short period following the adverse condition of October 11 and 16. There was no other evidence of increased mortality or retarded growth among the trout held in dilutions of the area effluent water. The growth of the trout was actually faster in the 1:3, 1:10, 1:50, 1:250 and possibly the 1:500 dilutions than in straight river water. This increased growth rate was probably the result of slightly higher water temperatures in the higher concentrations of the area effluent water.

The second chinook salmon experiment furnished a more sensitive test. Newly fertilized eggs were particularly susceptible to the presence of area effluent water and its accompanying higher temperatures and those held in the unrefrigerated effluent water and in the 1:3 dilution failed to develop. A large proportion of the eggs held in the 1:10 dilution did not hatch and egg mortalities significantly higher than those in the control lots could be demonstrated statistically in dilutions as high as one part effluent to five hundred parts of river water.

Growth and development during the fry and fingerling stages were greatly retarded in undiluted area effluent water and in the 1:3 dilution and further practically all of the fish held in these water conditions died. In the 1:10 dilution the rate of mortality among the fry and fingerling salmon was greatly increased, more deformed fish were present, and many of the surviving fish were emaciated, subnormal in size and susceptible to disease. However, some individuals were able to tolerate this concentration and made rapid growth. In dilutions of 1:50 or more the area effluent water did not appear to adversely effect either the growth or the mortality of the fry or fingerling chinook salmon.

EXPERIMENTAL DESIGN

General Program

A conference was held on the campus of the University of California, Berkely, California on June 9, 1945 at which the basic plan for studies to be

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conducted at the Fish Laboratory was discussed and formulated.[1] Attending this meeting were Col. S. L. Warren, Lt. Col. H. L. Friedell, Maj. A. A. White and Dr. Howland of the Medical Corps., Manhatten District, and Dr. L. R. Donaldson of the University of Washington.

It was the opinion of this group that the best way to determine the effect of the effluent water was to set up a series of dilutions in which fish could be reared. The program of fish studies was to be synchronized as nearly as possible with the expected sequence of events as they would effect the natural runs of fish in the river.

One series of experiments was to include the rearing of chinook salmon fingerlings, eggs, fry and advanced fry under the various water conditions available at the laboratory. Studies were to be made on mortality, growth in weight, growth in length and such other criteria on the physiological condition and vitality of the fish as would seem useful in evaluating the the effect of the effluent water.

A second series of experiments would use select steelhead-rainbow stock as test animals so that in addition to the data gathered on the salmon a series of spawning studies could be worked out to test the effect of the effluent on the reproductive capacity of the fish.

Laboratory Conditions

The laboratory facilities could accomodate twenty lots of fish. However, each dilution or water condition was to be run in duplicate, with the exception of the "control" lots in straight river water where it was thought best to run quadruplicates and thus nine conditions could be studied at one time. The dilutions to be used in the laboratory were arranged so that conditions both above and below those expected to exist in the river could be evaluated. After complete mixing in the Columbia a maximum effluent to river water ratio of 1:100 might be possible during the low river stage in November, December and January. An average ratio of 1:500 was expected. Since the salmon and trout normally would react unfavorably to the warm temperature of the effluent water, regardless of other physical and chemical characteristics, experimental conditions were to be included which would utilize cooled effluent water.

The proposed combination of dilutions was as follows:

Lots 1 & 2	100% effluent water.
Lots 3 & 4	100% effluent water, refrigerated.
Lots 5 & 6	1 part refrigerated effluent water to 500 parts river water.
Lots 7 & 8	1 part effluent to 50 parts river water.
Lots 9 & 10	1 part effluent to 100 parts river water.
Lots 11 & 12	1 part effluent to 250 parts river water.
Lots 13 & 14	1 part effluent to 500 parts river water.
Lots 15 & 16	1 part effluent to 1000 parts river water.
Lots 17, 18, 19 & 20 . . .	100% river water.

(1) "Program of Fisheries Experiment for the Hanford Field Laboratory" Transmitted to W. O. Simon by Major A. A. White, 9 July, 1945.

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Schedule

A pilot experiment of about six week's duration was to run from July 10 to August 20, 1945. This trial experiment was to serve as a testing period thus affording an opportunity for correcting mechanical defects and gaining a background of information to be used in determining the dilution levels to be used in subsequent experiments.

Following the pilot experiment a period of readjustment was to extend into September. During this period equipment was to be repaired, dilutions regrouped, and adjustments made to prepare the laboratory for the subsequent experiments.

The adult chinook salmon that migrate up the Columbia River during the spring and summer months reach maturity and spawn in September and October. The studies at the Fish Laboratory were to be arranged to follow, as nearly as possible, the expected stages of development of the progeny of such adults. As soon as the temperature of the Columbia had fallen to 13°- 14°C, that is when the water was cool enough to permit a normal development of eggs, fertilized chinook salmon eggs were to be brought to the laboratory and incubated under the various water conditions specified. Appropriate studies were to be made on the developing eggs and on the young fish or fry which hatched from the eggs. Following the egg and yolk sac fry experiments, the problem was to be continued using the young salmon which reached the feeding stage. A redistribution of the test animals using either a fresh stock or by dividing the "excess" control fish might prove opportune at this time.

The surviving steelhead trout used in the preliminary experiment during the summer were to be held in the various concentrations of area effluent water until late in December, 1945 or until such time as their size made it impractical to hold them in the laboratory troughs. They would then be returned to the holding ponds at the University where they could be reared to maturity.

EQUIPMENT ARRANGEMENT (1)

General

The Fish Laboratory is housed in a Pacific Hut providing approximately 1,280 square feet of floor space. Twenty hatchery troughs, each approximately twelve feet long by twelve inches wide by nine inches deep, are provided. These troughs are arranged in pairs, with a common wall between each pair. Each trough is provided with water supply, screens, baffles and drains as required to conduct the experiments.

The laboratory is also provided with food storage bins, a deep-freeze unit, a household refrigeration unit and an electric meat chopper for the

(1) The arrangement described here is, in many cases, somewhat different than that originally provided since changes were found necessary in order to maintain satisfactory operating conditions. The reader is referred to an earlier document, "Fish Laboratory Experience to December 25, 1945" for a description of the original arrangement and modifications that were found necessary.

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storage and preparation of fish food. Technical equipment includes microscopes, balance-type scales, an adding machine, a calculating machine and a limited amount of chemical glass ware. Portions of the building are partitioned off to provide office space and house toilet facilities.

River Water Supply

River water is supplied to the Laboratory via a six inch main originating from the emergency water supply line to the main Area Reservoir (Bldg. 182). Pressure from the River Pump House (Bldg. 181) elevates the water into a 250 gallon head tank before it enters the Laboratory. The head tank is equipped with a float valve and overflow to maintain a constant head (10 ft. H_2O). The elevation of this tank is slightly higher than that of the main reservoir, so its filling requires delivery from the River Pump House. In the event of an outage of the latter, the head tank may be by-passed to allow water from the reservoir to flow by gravity directly to the Laboratory.

A 16-mesh "top hat" strainer in the head tank prevents solids in the river water from entering the Laboratory and clogging control valves. The laboratory is supplied with the river water from the head tank via a 4-inch header and Troughs 5 to 20 inclusive, are fed by one-inch downcomers from this header. The flow to each trough is controlled by 3/8 inch gate valves.

Area Effluent Water Supply

Warm pile effluent from the Retention Basin (Bldg. 107) is combined with all other area effluents at the main sewer junction (Bldg. 1904). This mixed area effluent water is delivered to the Fish Laboratory via two centrifugal pumps, each powered by 7.5 H. P. induction motors. These pumps develop a pressure of approximately 80 psi against a closed discharge. The Pump House (Bldg. 147) was erected to house these pumps, only one of which is normally operated while the second is held as stand-by. In October 1945, a 20-mesh strainer was installed in the pump discharge header at the Pump House to prevent the passage of coarse solids to the head tanks of the Fish Laboratory. In May, 1946 this was supplemented by a sand trap.

A portion of the area effluent water delivered to the Fish Laboratory is directed into a 25 gallon head tank located on the same platform as the river water head tank. This tank also is equipped with a float valve and overflow to maintain a constant head (7 ft. H_2O). For the pilot tests, a 1 $\frac{1}{2}$ inch header from this tank was reduced to $\frac{1}{2}$ inch diameter to feed Troughs 7 to 16 inclusive. A $\frac{1}{4}$ inch downcomer with needle valve supplied each trough. However, satisfactory flows could not be maintained with this system. For later experiments a 12 $\frac{1}{2}$ gallon head tank was installed inside the laboratory and supplied by the $\frac{1}{2}$ inch header mentioned above. This small tank maintained a constant head of approximately 2 feet. A $\frac{1}{4}$ inch header fabricated from glass tubing syphoned area effluent water from this tank to Troughs 9 to 16 inclusive. A glass capillary tube of a diameter yielding approximately the desired flow was connected by rubber hose to the end of each $\frac{1}{4}$ inch downcomer tube from the header. Fine flow control was obtained by raising or lowering the capillary. The $\frac{1}{4}$ inch downcomers to Troughs 7 and 8 were also provided with rubber tubing connections for glass tube orifices.

Salmon and trout cannot survive for an extended period in water warmer

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than 24°C. Since the temperature of the area effluent water (25° to 30°) generally exceeds this limit some cooling was necessary before delivering it to Troughs 1 and 2. A second portion of the effluent water from the Pump House is directed into a series of cooling coils laid in a ditch in the floor of the laboratory. The water discharged from the fish troughs flows through this ditch and effects cooling of the effluent water in the coils, reducing the temperature to within 4° to 6°C of that of the river water. This partially cooled water is then directed into two commode-type reservoirs, complete with float valves which reduce the pressure and maintain a constant head of about 4 feet. These tanks are arranged to operate in parallel and each communicates with a common header supplying Troughs 1 and 2. The flow to each trough is regulated by a ½ inch gate valve.

A third portion of the area effluent water from the Pump House is directed into another series of cooling coils nearly identical with those described above. In this incidence they are called pre-cooling coils since final cooling of the water is accomplished in two freon refrigeration units of the evaporator-type, each with a capacity of approximately two tons. These refrigeration units are operated in parallel and the temperature of the water is controlled by a thermostatic switch which cuts the units in or out as required. The refrigerated effluent water is finally delivered to an insulated 25 gallon head tank located on the same platform with the two large head tanks previously described. This head tank for the refrigerated water is also equipped with a float valve and overflow line to maintain a constant head (7 ft. H_2O). From this head tank refrigerated water is supplied to Troughs 3 and 4 via 1½ inch insulated line. The flow to each trough is regulated by 3/8 inch gate valves.

During the pilot tests a small amount of refrigerated effluent water was also supplied to Troughs 5 and 6 via a ¼ inch header extension of the line supplying Troughs 3 and 4. Glass capillary tubes connected to downcomers from the ¼ inch header via rubber hose controlled the flow.

The effluent water headers supplying Troughs 1, 2, 3 and 4 were also cross-connected to the river water header so that these troughs could be temporarily supplied with river water in the event of an outage of the effluent water pumps.

<u>Miscellaneous</u>

An alarm system operates on the area effluent water supply and sounds when head is lost in the refrigerated effluent head tank. This alarm prevents an unnoticed failure of effluent water supply which would result in complete loss of flow to Troughs 1, 2, 3 and 4.

Two 4-point Leeds and Northrup temperature instruments record the water temperature in eight of the twenty troughs. These instruments are equipped with alarm trips which warn of abnormally high temperatures. A counting rate meter records the activity of the area effluent water in Trough 2.

Plate I shows the arrangement of the troughs and of the river and area effluent water supplies; the control panel of the refrigeration units can be seen in the background. Plate II shows the end of the laboratory opposite to

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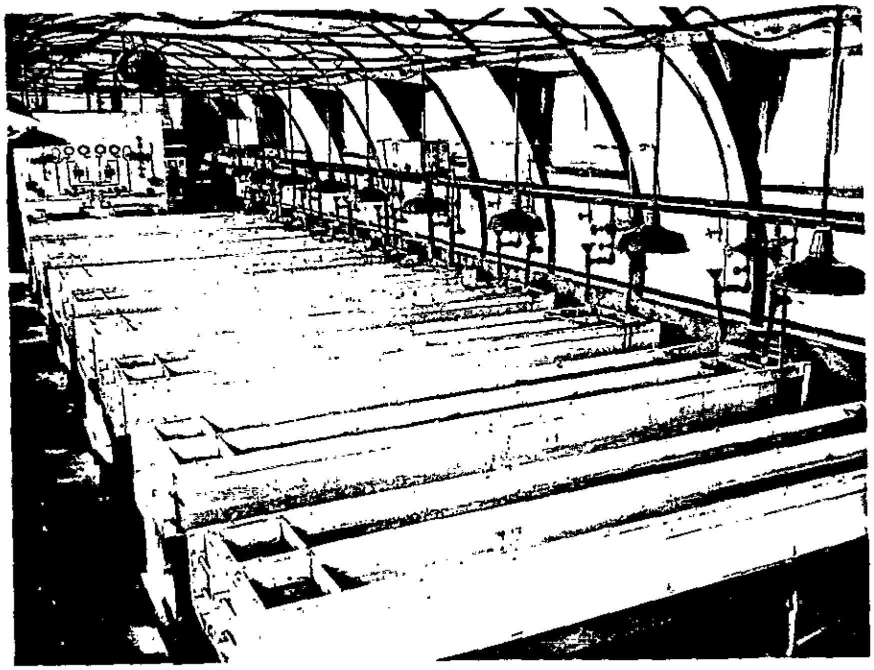

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PLATE I

General view of the Fish Laboratory

Troughs and water supply systems are shown in the foreground, refrigeration equipment in the background.

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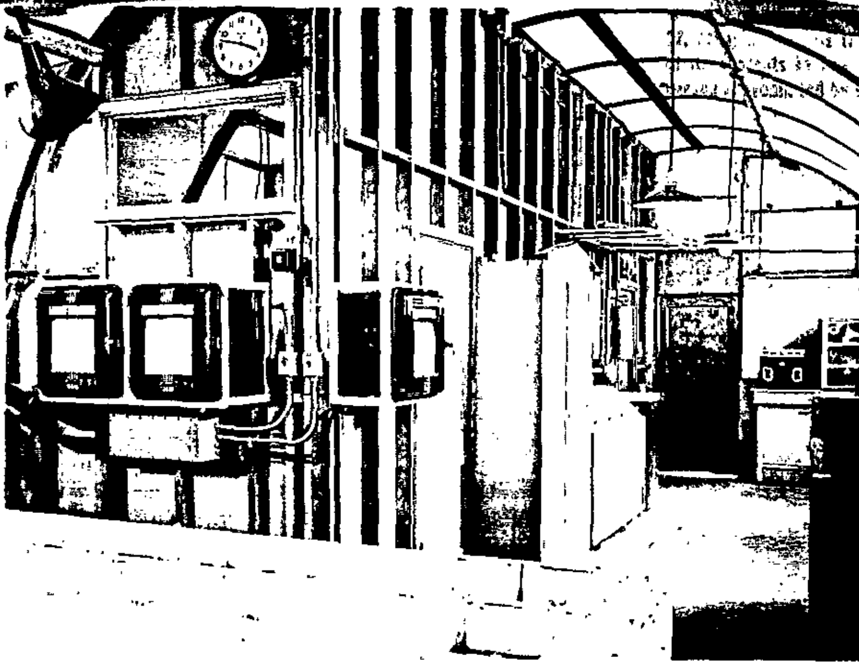

PLATE II

South end of Fish Laboratory
Office is behind partition

PLATE III

Food Preparation and Storage Equipment.

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that depicted in Plate I, some of the instrumentation is evident and the office is situated beyond the partition. Plate III shows the food storage and preparation area and equipment.

METHODS

Operating Personnel

The writer, designated a senior supervisor in the "P" Department was responsible for the Fish Laboratory and the experimental work. He was assisted by Mr. A. C. Schroder, an "A" operator regularly assigned to the day shift. The laboratory was operated during the 4-12 and 12-8 shifts, and during relief periods by an operator assigned for this purpose to each of the four shift crews working in the "P" Department portion of the 100-F Area.

Care of Test Animals

Care of the eggs and young fish followed standard hatchery practices. Every attempt was made to subject all of the test groups to the same amount of handling, care and treatment.

A large portion of the diet of the fish consisted of condemned beef liver obtained fresh from a slaughter house in Kennewick, Washington, approximately every two weeks. This liver was usually mixed with a prepared meal containing diatary supplements, and with frozen salmon carcass, or condemned canned salmon. A Mixture was made up fresh two to three times a week and the fish were fed all that they would consume without waste. Frequency of feeding ranged from about six feedings daily for advanced fry to two feedings daily for large fingerlings.

From time to time it was necessary to treat the fish to control disease or as a prophylaxis. Occasionally a commercial germacide, "Roccol", was used at a dilution of 1/50000 for a period of one hour. During such treatments the water in each trough was re-circulated by centrifugal pump for a few minutes to insure sufficient aeration of the water and to accomplish complete mixing of the chemical. Common salt was administered weekly during warm weather at a strength of three per cent for a period of one-half hour. On a few occasions it was necessary to add 0.2 per cent of the drug "Carbarsone" to the diet. The necessity for the use of these chemicals will be described in following sections.

Control of Water Flows

An attempt was made to maintain the flow of water through most of the troughs at a rate of five gallons per minute. However, the capacities of the pre-cooling coils and the refrigeration units was not great enough to properly cool this amount of water for Troughs 1, 2, 3 and 4. The flows to these four troughs then, was held as nearly as possible to three gallons per minute. The flows to two of the four control troughs on straight river water, Troughs 19 and 20, were also reduced to three gallon per minute so that any difference in the condition of the fish attributable to a flow of three rather than five gallons per minute, might be recognized. In the troughs receiving both river and area effluent water, the combined flow was regulated as nearly as practical to five gallons per minute.

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The rate of flow of both effluent and river water to each trough was measured twice each shift or six times a day. Any flow found to be incorrect was readjusted to the proper level. The rate of flow was measured by running the water into a glass graduated cylinder for a definite period, timed by a stop watch. Form sheets were provided so that a record of rate of flow to each trough could be kept. A typical record sheet for the chinook salmon experiment is shown in Appendix Table 1.

The gate valves or glass capillary tube tips described under "EQUIPMENT" maintained the desired rates of flow with the following success:

The 3/8 inch gate valves on the river water supplies maintained a flow within five per cent of the desired level about 97 per cent of the time. The glass capillary tube orifices on the effluent water supply maintained a flow within five per cent of the desired level about 85 per cent of the time.

The ½ inch gate valves on the effluent water supply to Troughs 1 and 2 and the 3/8 inch gate valves on the effluent water supply to Troughs 3 and 4 maintained flows within five per cent of the desired level about 94 per cent of the time.

Collection of Data

A daily record was kept of the number of fish dying in each trough. Mortalities among the developing eggs were removed at appropriate intervals. Weights of the fish were taken every two weeks and length measurements were made every four weeks. Observations on the condition, action and appearance of the fish were recorded as the occasion warranted. In addition to the continuous instrument record of the temperatures in eight of the troughs a daily record was made of the temperature in each pair of troughs.

In order to obtain the average weight of a lot of fish, a large sample or in some cases all of a group was counted out into a bucket of water. These fish were then emptied from the bucket into a net and the excess water allowed to drain off. Then the fish were placed in a pan of water previously counter-balanced on a scales. The increased weight of the pan of water represented the weight of the fish. At the termination of steelhead trout studies, the fish were weighed individually using a similar technique.

The fish were small and of uniform size at the start of experiments, and could be held for measurement by guiding them into a piece of glass tubing via a funnel. Their length was fixed on a pair of dividers which were then applied to a millimeter rule in order to obtain the reading. Larger fish were held for measurement by covering them with a wet sheer piece of cotton cloth which held them against a board. The fish could easily be seen through the wet cloth and were measured with dividers and a millimeter rule as before. In every case the "standard" length was taken, which is the distance from the tip of the snout to the base of the caudal fin rays.

During the incubation of fish eggs the time of removal of mortalities does not necessarily coincide with the time of death or stage of development of the embryo. In order to determine the stage of development at which each egg died it was first necessary to "clear" it or render it transparent. This was done by placing it in a solution of common salt which

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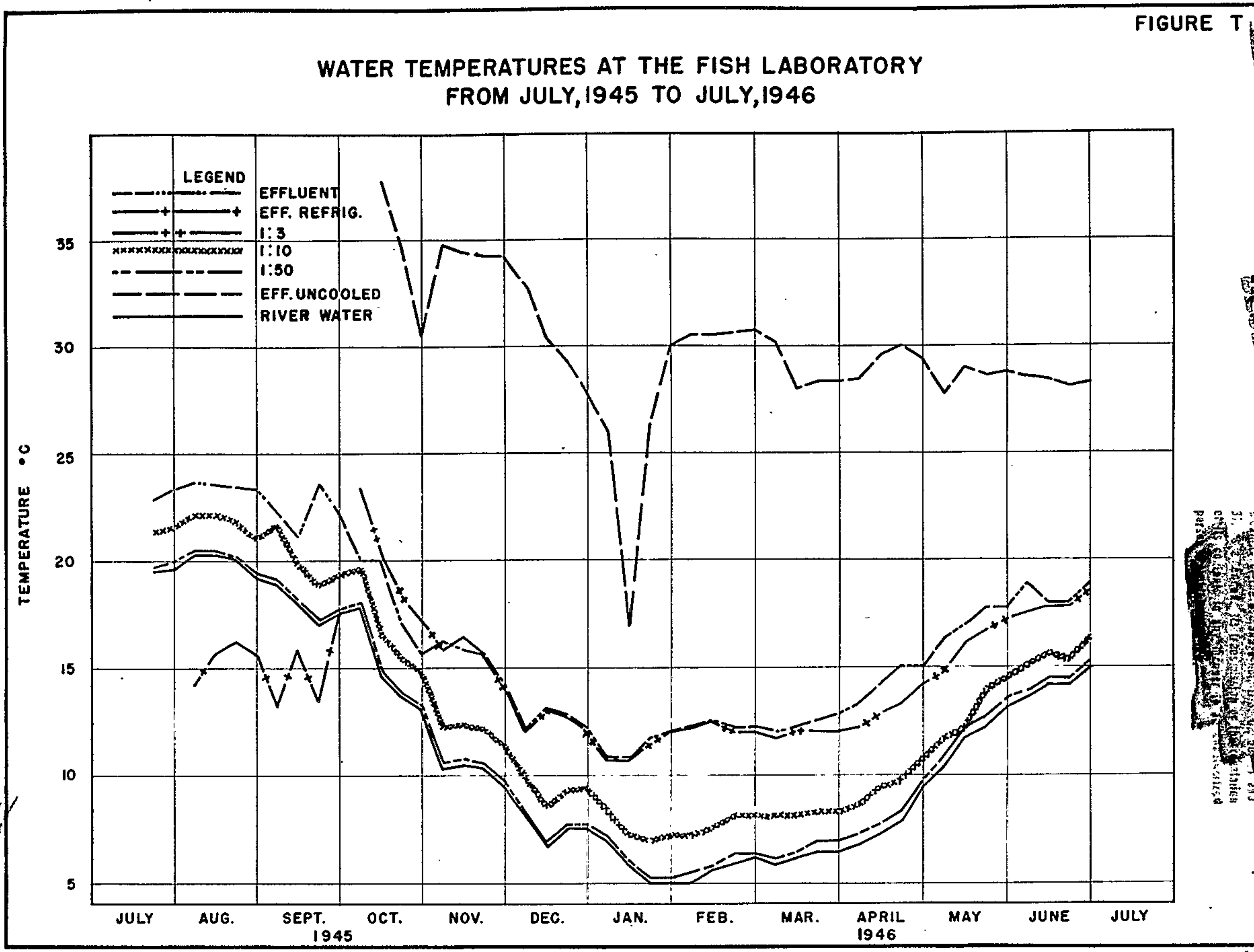
FIGURE T


WATER TEMPERATURES AT THE FISH LABORATORY
FROM JULY, 1945 TO JULY, 1946
LEGEND
EFFLUENT
EFF. REFRIG.
1:3
1:10
1:50
EFF. UNCOOLED
RIVER WATER
TEMPERATURE °C
35
30
25
20
15
10
5
JULY
AUG.
SEPT.
1945
OCT.
NOV.
DEC.
JAN.
FEB.
MAR.
APRIL
1946
MAY
JUNE
JULY

fish tank owned by the University of Washington. On arrival at the Fish Laboratory the salmon were tempered with river water for about forty-five minutes and then placed in Troughs 17, 18, 19 and 20 for further acclimatization to the Columbia River water before being subjected to the various dilutions of effluent water.

Experience and Conditions

Within twenty-four hours after arrival about ten per cent of the salmon developed a severe "gas bubble" disease which caused the fish to become "pop-eyed" and to develop gas blisters under the skin and membranes of the eyes and mouth. This disease was probably caused by the transfer of the fish into a new water environment of different physical and chemical properties and more specifically by the fact that the river water at the Fish Laboratory is supersaturated with dissolved gases. The disease gradually disappeared over a period of about three weeks with a resultant mortality of about fifteen per cent of the salmon. Many of the most severely effected fish improved rapidly after being placed in straight effluent water which had a lower gaseous content.

After the fish had become acclimated to the Columbia River water for a period of two weeks, they were divided into twenty lots of about 100 fish each and distributed among the troughs. In keeping with the experimental design an attempt was made to maintain the following water conditions in the various troughs:

Trough No.	Ratio of Area Effluent to River Water
1 & 2	100% effluent (partially cooled)
3 & 4	100% effluent (refrigerated)
5 & 6	1:500 (effluent water refrigerated)
7 & 8	1:50
9 & 10	1:100
11 & 12	1:250
13 & 14	1:500
15 & 16	1:1000
17, 18, 19 & 20	100% river water

At the time when effluent water was first started flowing into the troughs July 23, 1945, major piping changes and other alterations of the supply and cooling systems to Troughs 1, 2, 3 and 4 were still being made and these units could not be used. Neither was the effluent water being supplied to Troughs 5 and 6 refrigerated. During the first few weeks of the experiment considerable difficulty was experienced in controlling the flows of river and effluent water and thus the various dilution levels fluctuated over a wide range and could not be maintained within the desired levels for any length of time. By the latter part of August, 1945, most of the major mechanical difficulties had been corrected to a degree which permitted the operation of all troughs and the refrigeration units and thus made it possible to follow the specifications laid down in the original plan within limits approaching the figures given on page 10. During the middle of September, however, the fish in Troughs 3 and 4 were placed on straight river water for a period of three days while repair work was being done on the refrigeration units.

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During this experiment the temperature of the refrigerated effluent water was regulated to about 13°C., which is within the normal range for chinook salmon. This temperature was lower than that of the river water 19.5°C., which was above the optimum range for salmon. A colder temperature was used in order to help control disease and entirely eliminate the temperature factor.

Fish were first placed in straight effluent water (cooled to 22°C.) on July 27, 1945. This group was made up of 50 fish and was designated Lot 2-A. When first placed in the straight effluent water, the fish were somewhat nervous, and their respiratory movements increased in rate. Such a reaction could be expected, however, from the excitement of the transfer alone. A few hours later the fish showed a passive interest in food. Late in the afternoon a temporary outage of the effluent water pump caused a stoppage of flow to these fish for about fifteen minutes; this, however, did not result in obvious distress in the fish.

By the following morning all but eight of the fish of Lot 2-A were dead. Dissection of specimens which had recently died showed no apparent anatomical abnormalities. Since this was the first group of fish which had been subjected to the undiluted effluent water, it was not considered unusual at the time that most of them should be killed. Evidence accumulated later, however, indicates that this was an unusual occurrence and was probably due to the presence in the effluent water of a soluble oil ("Calol") used during pile metal displacement operations.

A second group of fish made up of 50 individuals which had been held in reserve in straight river water and a third group composed of 52 individuals removed from various other troughs because they had "gas bubble" disease were placed in the partially cooled effluent water on July 28, 1945. The diseased fish were used to avoid a needless sacrifice of many good fish, since it was expected that most of them would be killed by the effluent water during the first twelve hours' exposure, as had happened to Lot 2-A. However, the expected heavy mortality did not materialize, and the "gas bubbles" began to disappear from the diseased fish.

A fourth group of fish, which was made up of 50 salmon that had been held in reserve in straight river water was placed in the partially cooled effluent water on August 1, 1945. Because of space limitations it was necessary to combine these fish with those surviving in Lot 2-A (which now toteled 6). The new combination was designated Lot 2-B. Likewise, it was necessary to combine the second group with the third group (recovering from the "gas bubble" disease) to form a new group which was designated Lot 1-B.

During the next four weeks the mortalities in Lots 1-B and 2-B were consistently higher than in any of the other lots, but no great percentage of the fish died during any one twelve-hour period, as was experienced by Lot 2-A on July 27-28.

Rather than liberate the salmon in August, as was originally scheduled, it was decided that they should be held for another few weeks with the hope that better data obtained under more uniform experimental conditions could be accumulated. Since disease had taken a heavy toll of the salmon, the lots were regrouped in order to equalize the number of fish in each trough. This regrouping was done on August 27, 1945, and resulted in each trough being stocked with about 44 fish. So few fish remained alive in the straight effluent water (Lots 1-B and 2-B) that these were combined into a single group and supplemented with surplus fish from other troughs to bring the total for the lot up to 23. This group was then designated 3-C and held in refrigerated effluent water in Trough 3. The other troughs containing undiluted effluent water (that is, Nos. 1, 2 and 4) received new stocks of fish obtained by thinning out stocks in other troughs. The number of fish in each of the other troughs was adjusted by removing an appropriate number from those with large stocks and placing them in the troughs which were understocked. Insofar as was possible, the transfer of fish was made between troughs of like water conditions; otherwise the shift was made from a lesser concentration of effluent to a greater one. The group of fish in each trough was still designated by lot number which corresponded to the position of the trough, but the suffix "C" was added to show that a regrouping had been made.

On the morning of August 31, the fish in Troughs 1 and 2 would not eat - - they were quite weak and susceptible to handling during a treatment with "Roccol". In the afternoon these fish were listless and showed little interest in activity around them. Many of them swam near the surface, often inclined with their snouts out of water. Respiratory movements were labored, but they were not gasping for oxygen. A mortality started during the late afternoon and increased during the evening. By 3:00 A. M. on September 1, all of the fish were dead. Although the fish in Troughs 3 and 4 did not appear to be similarly distressed, the mortality in these groups increased after this time and continued at a rather high rate.

The occurrence of this heavy mortality in Lots 1-C and 2-C on August 31, was very much like that which occurred in Lot 2-A on July 27-28, and took place under similar circumstances. In each case the 100-F Pile was undergoing metal displacement, and "Calol" was entering the effluent water. Such sudden mortalities did not occur again during this experiment.

For several hours on each Monday and Tuesday, the fish in the undiluted effluent water were subjected to an extremely heavy concentration of ferric sulphate ("Ferrifloc") sludge, which was flushed into the sewer from the water purification area. While this sludge was in the water, the gills of the fish appeared to be slightly irritated, as was indicated by their opercula being held in an extended position. During this time the fish were more nervous than usual, their respiratory rate increased slightly, and they refused food. However, their actions soon returned to normal when the water cleared up. It would seem that the ferric sulphate sludge affected the fish as a mechanical irritant rather than a chemical toxin.

Serious disease conditions of various types existed throughout the experiment, which makes much of the data unreliable. Such conditions were anticipated during the later part of the summer, however, since the physiological processes of the fish were changing to adapt the fish to a salt water environment. Further, the summer temperature of the Columbia River water was considerably above the optimum range for chinook salmon and favored the existence of disease organisms. Throughout the period of retention in the laboratory troughs, the salmon were highly nervous and almost continually fought to escape and migrate downstream. Often they showed only a passive interest in food. Late in July, external parasites common to fish began to

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appear, and early in August, an epidemic of <u>Boccilus columnaris</u> spread through the fish. A series of salt baths given on alternate days were effective in ridding the fish of parasitic protozoans, but prophylactic treatments with "Roccol" only partially controlled the bacterial infection.

The 507 surviving chinook salmon fingerlings were liberated into the Columbia River near the 100-F Area on September 26, 1945.

Mortalities

A daily record was kept of the number of fish dying in each lot. These daily records have been condensed into weekly periods, and a summary of them is given in the appendix. Table 2 covers the preliminary part of the study, and Table 3 the second part after the lots were regrouped on August 27. These data have been further condensed by combining lots which were subjected to like dilutions of the effluent water, and parts (A) and (B) of Table I show these totals, together with the percentages for the early and later parts of the experiment, respectively. Graphic representations of parts (A) and (B) of Table I are shown in Figure 1, parts (A) and (B).

Figure I clearly shows the extremely high mortalities which took place in all groups subjected to straight effluent water, either only partially cooled or refrigerated. In both parts (A) and (B) the high mortality in the effluent groups, Lots (2-A) and (1-C and 2-C), which occurred during the first week, represents the unusual and sudden death of fish in these lots on July 27-28 and August 31, respectively. Aside from those groups which were held in undiluted effluent water, the variations in the mortalities of the various experimental groups from that of the river water control groups are not considered as attributable to variations in the concentration of effluent water. As pointed out in the section above, the fish in this experiment suffered severely from disease. Mortalities from disease varied greatly from trough to trough and tended to obscure any effect which the different dilutions of effluent water might have upon the mortality. The wide variation among individual lots of the control group, Appendix Tables 2 and 3, is evidence of this. Further, part (A) of Figure I indicates an inverse relationship between mortality and concentration of effluent water, straight effluent being excluded. Although the control mortality in part (B) was lower than in any group which was subjected to effluent water, the crossing of curves and the final arrangement, which again generally shows an inverse relationship between mortality and amount of effluent water, strongly indicate that the factor controlling mortality was not the concentration of effluent water.

Growth in Length and Weight

The fish were weighed at the beginning and end of the preliminary period and at the beginning, middle and end of the second period after regrouping the lots. Appendix Tables 4 and 5 summarize the result of these weighings. In Table II, parts (A) and (B), the weight of lots in similar water conditions have been combined. Part (A) does not show weights for the fish held in undiluted effluent water since the majority of such fish lived but a short period of time. The data from part (B) of Table II, covering the period when experimental conditions were reasonably constant, are shown graphically in Figure 2.

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TABLE I MORTALITIES OF CHINOOK SALMON FINGERLINGS HELD IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER

(A) Early Results Before Mechanical Difficulties were Corrected

Type of Water	Effluent			Effluent			Effluent			1:50			1:100			1:250			1:500			1:100			River Water		
Lot Nos.	2A			1B			2B			7 & 8			9 & 10			11 & 12			5 & 6 13 & 14			15 & 16			3, 4, 17, 18, 19 & 20		
No. of Fish	50			94			56			200			200			200			400			200			490		
Date Week	Mort	%	cum %	Mort	%	cum %	Mort	%	cum %	Mort	%	cum %	Mort	%	cum %	Mort	%	cum %	Mort	%	cum %	Mort	%	cum %	Mort	%	cum %
7/25-31 1	44	88	88	(Not yet started)						12	6.0	6.0	18	9.0	9.0	24	12.0	12	23	5.7	4.7	9	4.5	4.5	54	11.3	11.3
8/1-7 2	Ends			22	23.4	23.4	21	37.5	37.5	18	9.0	15.0	34	17.0	26.0	33	16.5	28.5	45	11.2	16.9	38	19.0	23.5	47	9.8	21.1
8/8-14 3				20	21.3	44.7	27	48.2	85.7	20	10.0	25.0	15	7.5	33.5	25	12.5	41.0	71	17.8	34.7	66	33.0	56.5	88	18.3	39.4
8/15-21 4				25	26.6	71.3	6	10.7	96.4	16	8.0	33.0	11	5.5	39.0	6	3.0	44.0	41	10.3	45.0	25	12.5	69.0	58	12.0	51.4
8/22-27 5				20	21.3	92.6	1	1.8	98.2	16	8.0	41.0	5	2.5	41.5	12	6.0	50.0	16	4.0	49.0	8	4.0	73.0	18	3.8	55.2
Total				87	92.5		55	98.2		82	41.0		83	41.5		100	50.0		196	49.0		146	73.0		265	55.2	

(B) Later Results After Regrouping Lots

Type of Water	Effluent			Refrigerated Effluent			1:500 Refrig. Eff.			1:50			1:100			1:250			1:500			1:1000			River Water		
Lot Nos.	1C & 2C			3C & 4C			5C & 6C			7C & 8C			9C & 10C			11C & 12C			13C & 14C			15C & 16C			17C, 18C, 19C & 20C		
No. Fish	86			67			85			89			90			89			87			87			174		
Date Week	Mort	%	cum %	Mort	%	cum %	Mort	%	cum %	Mort	%	cum %	Mort	%	cum %	Mort	%	cum %	Mort	%	cum %	Mort	%	cum %	Mort		cum %
8/29-9/3 1	86	100	100	10	14.9	14.9	13	15.3	15.3	8	8.9	8.9	7	7.8	7.8	6	6.8	6.8	8	9.2	9.2	12	13.8	13.8	9	5.2	5.2
9/4-10 2	Ends			32	47.7	62.6	6	7.05	22.3	3	3.4	12.3	6	6.7	14.5	10	11.2	18.0	8	9.2	18.4	5	5.7	19.5	9	5.2	10.4
9/11-17 3				15	22.4	85.0	6	7.05	29.4	4	4.5	16.8	12	13.3	27.8	13	14.6	32.6	1	1.1	19.5	6	6.9	26.4	7	4.0	14.4
9/18-26 4				2	3.0	88.0	7	8.2	37.6	3	3.4	20.2	5	5.5	33.3	3	3.4	36.0	2	2.3	21.8	11	12.6	39.0	4	2.3	16.7
	86	100		59	88.0		32	37.6		18	20.2		30	33.3		32	36.0		19	21.8		34	39.0		29	16.7	

9 2 1 2 7 9 4 7 9

FIGURE 1

MORTALITIES OF CHINOOK SALMON FINGERLINGS HELD IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER

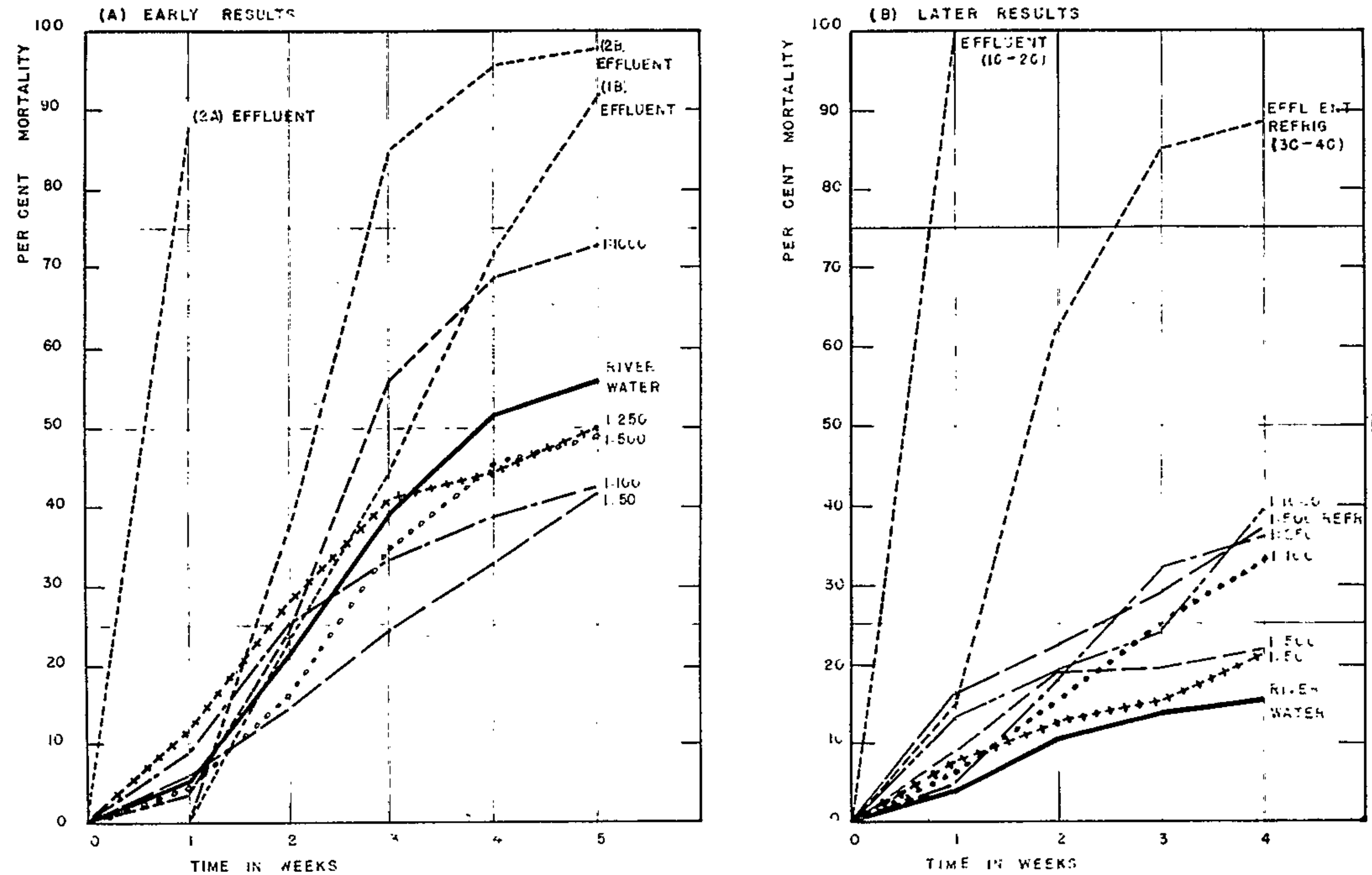


TABLE II

AVERAGE WEIGHT IN GRAMS OF CHINOOK SALMON FINGERLINGS HELD IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER

(A) Preliminary Weights of Surviving Lots.

Type of Water	1:50	1:100	1:250	1:500	1:1000	River Water
Lots included	7 & 8	9 & 10	11 & 12	5, 6, 13 & 14	15 & 16	3, 4, 17, 18, 19 & 20
No. of Fish at start	200	200	200	400	200	500
7/24/45	9.35	9.37	8.69	8.96	8.92	9.53
8/27/45	13.19	13.30	13.43	12.94	14.30	13.27

(B) Weights After Regrouping of Lots on August 27, 1945.

Type of Water	Effluent	Refrigerated Effluent	1:500 Refrig.Eff.	1:50	1:100	1:250	1:500	1:1000	River Water
Lots included	1C & 2C	3C & 4C	5C & 6C	7C & 8C	9C & 10C	11C & 12C	13C & 14C	15C & 16C	17C,18C,19C,20C
No. of Fish at start	86	67	85	89	90	89	87	87	174
8/28/45	12.88	11.84	13.92	13.12	13.10	13.35	12.13	13.20	13.50
9/10/45	All Dead	13.21	15.07	15.01	14.47	15.03	13.93	14.83	15.20
9/24/45		15.80	16.19	17.17	15.70	15.54	15.45	16.50	17.30

TABLE III

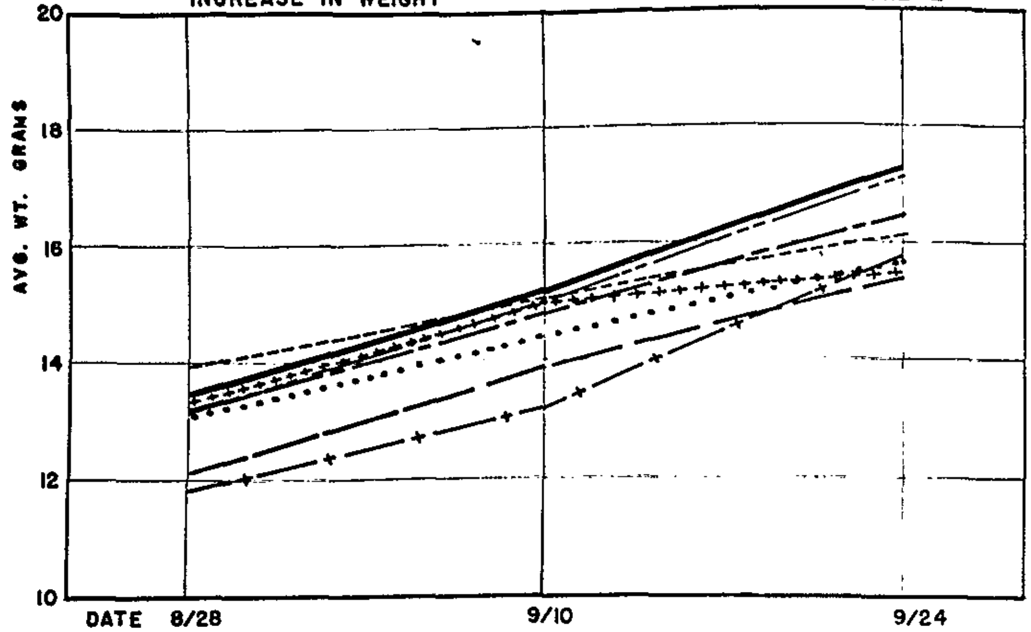
AVERAGE LENGTHS IN MM OF CHINOOK SALMON FINGERLINGS HELD IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER

Type of Water	Effluent	Refrigerated Effluent	1:500 Refrig.Eff.	1:50	1:100	1:250	1:500	1:1000	River Water
Lot Nos.	10 & 20	30 & 40	50 & 60	70 & 80	90 & 100	110 & 120	130 & 140	150 & 160	170,180,190,200
No. of Fish on 8/29-30/45	84	66	82	86	88	85	84	83	173
8/29-30/45	97.8	97.1	100.8	94.6	94.9	99.8	101.2	100.2	100.2
9/24-25/45	No fish	103.0	105.7	105.9	103.8	103.5	102.3	106.3	106.8

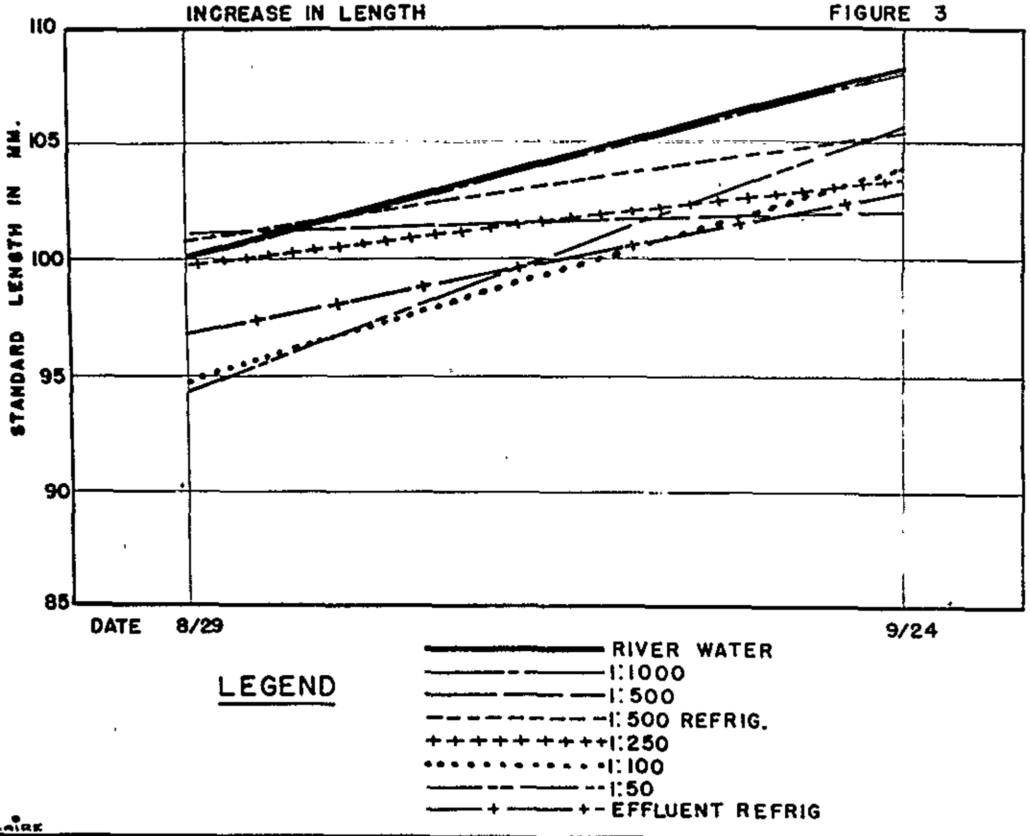
GROWTH OF CHINOOK SALMON FINGERLINGS

HELD IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER

INCREASE IN WEIGHT — FIGURE 2



INCREASE IN LENGTH — FIGURE 3



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Although the weight of the control group was slightly higher than that of most other groups, it was closely paralleled by that of the group in the 1:50 dilution, with the exception of the straight effluent water, this was the highest concentration used. Actually the size variation between all of the groups is not large and cannot justifiably be attributed to the different water conditions.

Lengths of the fish were taken only at the beginning and end of the second period. These measurements, grouped into class intervals of five millimeters, are shown as frequencies in Appendix Tables 6 and 7. After combining lots held in like water conditions the means of these data are presented in Table III and graphically in Figure 3. The results are much like those for the weights and the remarks given there will apply equally well to the length data.

The variation in size and in rates of growth between the various groups is not considered great nor due to variations in water conditions. These data are not considered worthy of further statistical treatment since the variations which did occur could better be interpreted in the light of uncontrolled conditions rather than as the result of subjecting the fish to different dilutions of area effluent water.

Discussion

Because of the difficulties which were encountered in the operation of flow controls and the refrigeration units the chinook salmon fingerlings were held at the laboratory for about twice as long as was originally scheduled. Holding these fish for a considerable time past their normal migration period in the warm summer temperatures of the Columbia River water lead to disease difficulties which were not easily controlled. The experimental conditions were so upset by the early improper functioning of equipment and later by disease that definite conclusions as to the effect of dilutions of the effluent water on fingerling chinook salmon could not be drawn. It was apparent, however, that undiluted area effluent water, either partially cooled or refrigerated to within the normal temperature range of salmon, was not suitable for the survival of the fish and, occasionally, was quickly lethal.

In spite of the many difficulties, the primary purpose of this first experiment, which was to test and perfect the equipment, was accomplished satisfactorily. Further, some general knowledge of the effect of the effluent water at various dilution levels was gained.

STUDIES ON STEELHEAD TROUT FINGERLINGS

Purpose

The early part of this experiment was carried out at the same time as the pilot studies on the chinook salmon just described, and thus also aided in the development of equipment and techniques and in the selection of dilution levels of area effluent water to be used in later tests.

Secondly, steelhead (rainbow) trout are one of the most valuable sports fish of the Columbia River system, and in addition, are of considerable commercial value to fishermen of the State of Oregon. Since, trout of this species could be expected to spend at least the first years of their life and

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perhaps the greater portion of their existance within the influence of water discharged from the Pile Areas, information on the effect of the effluent water on these fish was of high importance.

The original experimental design further planned that some of the trout which had been subjected to the area effluent water be raised to maturity and their reproductive capabilities studied. Facilities for raising fish to maturity are not available at the Fish Laboratory and it was originally intended that ponds at the University of Washington be used for these later studies. However, an extended program at the University required the use of all facilities available there. Further, only a very few fish of suitable exposure for such studies survived at the Fish Laboratory and thus it was decided that this phase of the experiment should be cancelled for the present, but, if possible, should be done at a future time.

Origin of the Test Animals

The trout used in this experiment were obtained from the stock reared at the School of Fisheries, University of Washington. This strain of fish has been selectively bred at the University for several generations and their reproductive capabilities are quite well established. At the beginning of these studies the fish were three to four months old and averaged approximately two and one half inches in length, having been hatched from eggs at the University early in the spring.

The 3062 trout used were transferred from the University of Washington to the Fish Laboratory on July 16, 1945 in a transportation tank owned by the School of Fisheries. On arrival the fish were tempered with Columbia River water for about one hour, then counted and placed in Troughs 13 through 20. Screen partitions in the troughs separated the trout from the salmon used in the pilot experiment. All of the fish were held in straight river water for several days for acclimatization before being subjected to effluent water.

Experience and Conditions

Preliminary Studies

The trout were in excellent condition upon arrival at the Fish Laboratory and covers had to be kept on the troughs to prevent them jumping out. Fortunately, the trout were more resistant to the factors causing "gas bubble" disease and did not suffer from the gas blisters as did the salmon. A very few individuals did, however, show evidence of the disease.

On July 29th, the trout were counted into 20 groups of 150 and each group was placed in one of the troughs. Since Troughs 1, 2, 3 and 4 were not yet in operating condition, the fish allocated to these troughs were held in reserve in compartments of Troughs 17, 18, 19 and 20.

The water conditions to which the trout were subjected in the various troughs were the same as for the salmon in the pilot experiment and were as follows:

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TROUGH NO.	RATIO OF EFFLUENT TO RIVER WATER	RATE OF FLOW
1 & 2	100% effluent water, partially cooled (3^o to 5^oC above river water temperature)	3 g.p.m.
3 & 4	100% effluent, refrigerated to about 13^oC.	2 g.p.m.
5 & 6	1:500 effluent refrigerated	5 g.p.m.
7 & 8	1:50	5 g.p.m.
9 & 10	1:100	5 g.p.m.
11 & 12	1:250	5 g.p.m.
13 & 14	1:500	5 g.p.m.
15 & 16	1:1000	5 g.p.m.
17, 18, 19 & 20	100% river water	5 g.p.m.

Trout were first placed in Troughs 3 and 4 on August 1st and 2nd, respectively. Since the refrigeration units were not then operating, the area effluent water entering these troughs was only partially cooled. During the later part of August, the refrigeration units were operated most of the time but frequently had to be shutdown for repair or adjustment and thus the fish in Troughs 3 and 4 were subjected to refrigerated effluent, partially cooled effluent and, at times, straight river water. Obviously, data collected during this early period were not very reliable but in general mortalities among the trout in Troughs 3 and 4 were very similar to those in the other troughs.

The results obtained during the first month were further complicated by disease conditions among the fish. The trout were subjected to the same parasites as the salmon but seemed more resistant to them and made a better recovery. Repeated baths of three per cent salt soon rid the trout of Cyclocheta, a parasitic protozoan. A serious infection of B. columnaris caused the death of many fish but was finally brought under control by repeated treatments with "Roccol".

By August 26, 1945, major equipment difficulties had been corrected so that Troughs 1, 2, 3 and 4 could be operated properly, and disease organisms had also been largely eliminated. An opportunity was thus afforded for starting anew with the expectation that subsequent data would be reasonably accurate and usable. At this time the group of fish which had been held in Trough 3 was moved into Trough 2 and one of the groups held in reserve in river water was placed in Trough 3. The other group which had been held in reserve in river water was moved into Trough 1. These changes were made in order that comparable groups of fish would be present in Troughs 1 and 3, and 2 and 4, respectively, those in Troughs 1 and 3 having just been placed in the effluent water for the first time.(1)

The factors in the effluent water on August 31, 1945 which were lethal to the salmon in Troughs 1 and 2 also had their effect upon the trout. During the afternoon, the trout in Troughs 1 and 2 were listless, showed little interest in activity around them and refused food. A few fish died during the late afternoon, and several more during the night. (All of the salmon in troughs 1 and 2 were dead by 3:00 A. M.) On the morning of

(1) Subsequent results showed that the previous history of these groups, had little effect upon their later tolerance to the area effluent water; that is, Lots 1 and 2 behaved alike and 3 and 4 behaved alike.

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September 1st, the surviving trout in Troughs 1 and 2 were quite ill. Many were swimming near the surface of the water and breathing was rapid. Occasionally an individual would become too weak to swim upright, would lose equilibrium, eventually sink to the bottom and die. Several specimens which were near death were dissected and examined but, other than an enlarged gall bladder in one, they appeared to be in good condition. Several more fish died during the day which raised the total for these two troughs to about 20 per cent.

Since the fish were still very ill and refused food in the afternoon of September 1st, straight river water was turned into Trough 1, to see if the rate of mortality could be checked by river water. However, it would seem that the factor in the effluent water which caused the heavy loss had passed since the rate of mortality dropped appreciably in both Trough 1 and Trough 2 and the action of the fish improved. Effluent water was again turned into Trough 1 on September 6th. The trout in Troughs 3 and 4 suffered a partial loss of appetite for a few days after September 1st, but otherwise seemed unaffected by the adverse conditions. As pointed out in the salmon experiment, evidence accumulated later indicated that "Calol" was the cause of distress among the fish.

A loss of appetite and a comparatively high rate of mortality continued in Troughs 1 and 2 until the termination of this test. These lots were further troubled by an infestation of Ichthyopterus, a common fish parasite. This parasite was probably able to establish itself on these fish because of their weakened resistance and the higher water temperature in these lots. Ichthyopterius did not appear in other lots and was finally eradicated from Troughs 1 and 2 by repeated treatment with strong salt and by turning a strong flow of river water into the troughs for about one week.

By the first week in October, the trout had increased in size to a point where it was necessary to reduce the number of fish in each trough to 50. This was done on October 11, 1945 and the surplus fish, which amounted to 1066, were liberated into the Columbia River adjacent to the 100-F Area. The high mortalities in Troughs 1 and 2 had so reduced the number of fish in these lots that those in Trough 2 were combined with those in Trough 1 to form a new group designated Lot 1A. A new stock of fifty fish, obtained from surplus from the river water control lots, was placed in Trough 2 and designated as Lot 2A.

Final Studies

The results obtained during August and September 1945 at the Fish Laboratory, indicated that a more complete knowledge of the problem might be gained if certain changes were made in the concentrations of area effluent water being used. Under the original set of concentrations, which had been chosen arbitrarily, there was a considerable difference between the action of the fish in undiluted effluent water and in the next highest concentration, one part of effluent to fifty parts of river water. It was proposed the two new concentrations be used in order to bridge this gap. The proposed changes were discussed on September 28, 1945 at a conference held in Richland, attended by Dr. L. R. Donaldson of the University of Washington, Major A. A. White of the Medical Corps. (Manhatten District), Mr. H. Thayer of the U. S. Engineers, and Dr. S. T. Cantril and Mr. R. F. Foster of the du Pont Company. The following changes were agreed upon:[1]

(A) Substitution of a dilution of one part area effluent to three parts river water for one part refrigerated effluent to 500 parts river water in Troughs 5 and 6. The 1:500 dilution using refrigerated effluent water was duplicated with a 1:500 dilution using unrefrigerated effluent water. Since the actual temperature difference of the resultant mixtures was not appreciable, little experimental evidence would be lost by the elimination of this water condition.

(B) Substitution of a dilution of 1:10, area effluent to river water, for the 1:100 dilution being used in Troughs 9 and 10. It was surmised that the elimination of the 1:100 dilution would not interrupt the series as greatly as the elimination of any one of the other dilutions.

At the time the lots were reduced to fifty fish each, October 11th, it was convenient to make the above changes in the experimental design. At the same time the rate of flow to Troughs 3 and 4 was increased from two to three gallons per minute. This was made possible by improved efficiency of the refrigeration units which could not adequately cool a larger volume of water. The temperature of the refrigerated effluent water was raised, on October 1st, from 13°C to 17.5°C in order to make it the same as that of the river water. Subsequently, the temperature of the refrigerated effluent water was adjusted to follow the changes in temperature of the river water. In order that any difference in results due to the lower rate of flow in Troughs 1, 2, 3 and 4 (3 gpm in contrast to 5 gpm in other troughs) could be appreciated, the flow in two of the control troughs, Nos. 19 and 20, was also reduced to three gallons per minute.

These changes resulted in the following new water conditions in the various troughs:

TROUGH NO.	RATIO OF EFFLUENT TO RIVER WATER	RATE OF FLOW
1 & 2	100% effluent, partially cooled	3 g.p.m.
3 & 4	100% effluent, refrigerated to river water temperature	3 g.p.m.
5 & 6	1:3	5 g.p.m.
7 & 8	1:10	5 g.p.m.
9 & 10	1:50	5 g.p.m.
11 & 12	1:250	5 g.p.m.
13 & 14	1:500	5 g.p.m.
15 & 16	1:1000	5 g.p.m.
17 & 18	100% river water	5 g.p.m.
19 & 20	100% river water	3 g.p.m.

In order to keep the fish in the 1:50 dilution level at a consecutive place in the series of troughs, they were moved from Troughs 7 and 8 into Troughs 9 and 10. The fish from Troughs 9 and 10 being used now for

(1) "Proposed Changes in Dilutions of Area Effluent Water at 146 Bldg.", R. F. Foster to C. N. Gross, October 4, 1945.

the 1:10 dilution level were moved down into Troughs 7 and 8. A suffix "A" was added to the lot numbers corresponding to trough in which new water conditions existed or where different groups of fish had been placed in order to avoid confusion in the data.

During the night of October 11-12, 1945, immediately following the start of the second and final phase of this experiment where the new water conditions were in effect, adverse factors were again present in the area effluent water which caused the death of many fish in Troughs 1, 2, 3, 4, 5 and 6. The action of the distressed fish was like that shown by the fish affected on August 31st, and September 1st, referred to above. The fish in in Troughs 1 through 6 continued to show considerable distress on October 12th and by 4:00 P. M. of that day the following mortalities had occurred:

Lot 1A	45 per cent
Lot 2A	100 per cent
Lot 3	90 per cent
Lot 4	94 per cent
Lot 5A	36 per cent
Lot 6A	38 per cent

Examination of several of the dying fish revealed no obviously abnormal condition except that the color of the gills of these fish was a little lighter and brighter than that of the control fish which were not effected. Samples of the effluent water collected during the early morning of October 12th, showed normal amounts of residual chlorine and dissolved oxygen. However, as on other similar occasions, metal in the 100-F Pile was being displaced and "Calol" was present in the area effluent water.

This was the first occasion where the fish in the refrigerated effluent water had been severely effected, however, the temperature of the refrigerated effluent was higher at this time than on previous occurrances since it had been adjusted up to that of the river water. Nevertheless, conditions were sufficiently adverse to cause a considerable mortality even where the effluent was diluted with three parts of river water. The fish in Troughs 7 through 16 seemed uneffected by the unusually adverse condition of the effluent water.

In the lots which were effected some mortality continued and the fish refused food for several days. By October 16th, only two fish remained in refrigerated effluent water so these were combined with a new group of ten fish moved into Trough 3 from a reserve group which had been held in straight river water. The new stock in Trough 3 was designated Lot 3A.

Similarly adverse conditions were again anticipated on October 16th, since pile metal displacement was again being made. A careful watch was kept of the fish and samples of the effluent water were collected at frequent intervals during the day. In the late afternoon the fish in Troughs 1 through 6 appeared to have sore gills as evidenced by extended opercula, and breathing was more rapid than normal. This may have been due in part to ferric sulphate sludge coming through in the effluent water. During the late evening, the fish in Trough 1 were obviously uneasy but not greatly distressed; during the night two of the surviving twenty-three died.

In Lot 3A, however, which was made up principally of fish that had not previously been in effluent water, the trout gradually became more sluggish during the evening and by morning, eight of the twelve fish were dead. The fish in Troughs 5 and 6 showed some listlessness during the evening but were not seriously effected. Five of the remaining fifty-eight died during the night. The fish in these first six troughs showed a lack of interest in food for several days more. Fish in other troughs in the laboratory were not effected.

Since only four fish remained in Lot 3A on October 18th, ten more fish from a reserve stock in straight river water were moved into Trough 3 with them. The new group was designated Lot 3B.

Special observations and water samples were taken on subsequent days when the 100-F Pile was undergoing metal displacement but serious difficulties were not encountered during the experiment.

The "Calol" used during the pile metal displacement operations was suspected of causing the distress and death of the fish in the undiluted area effluent water on the occasions mentioned above. To test this hypothesis, five trout were subjected to a concentration of 10 ppm "Calol" in river water for a period of eleven hours on November 20, 1945. The fish were obviously effected by the oil since they became somewhat listless, showed symptoms of sore gills and refused food. When the oil was stopped the fish began to recover and by the morning of November 21st, their actions were near normal and their gills no longer appeared irritated. They refused to take food until November 22nd, however. None of the fish died or were in great distress. This test was repeated on November 30, 1945 in the straight effluent water of Trough 1. After being exposed to the oil for about six hours, the fish became quite ill, and with continued exposure they became listless and weak, their respiratory rate increased and they "coughed" almost continually. After nine hours the fish began to die and twelve hours after the start of the test four of the five fish were dead. The fifth fish, the smallest of the group, refused food for several days and died about two weeks later.(1)

The remainder of this experiment was completed without further unusual incidences or serious variation in the conditions under control. The surviving steelhead trout were liberated into the Columbia River adjacent to the 100-F Area on January 7, 1946.

Mortalities

Daily mortalities have been combined by weeks and the results presented in Appendix tables. Table 8 presents the data obtained after disease and mechanical difficulties had been eliminated and before the lots were reduced to fifty fish each. Table 9 presents the data obtained after the number of fish was reduced and new water conditions were set up. The difference in total mortality between each individual lot and the average of the

(1) For further details on these and other studies on "Calol" the reader is referred to "Occasional Heavy Mortalities Among Fish Held in 100-F Area Effluent Water and Some Effects of "Calol" on Steelhead Trout Fingerlings" - - R. F. Foster to File, May 2, 1946.

[redacted]

four control lots has been tested for significance by the method of Chi-square.[1] Values which are probably significantly different from the control have been underlined - - those of questionable significance underlined with dots and those not significantly different have not been underlined.

In Table 8 none of the control troughs had mortalities significantly higher than their average, which indicates that factors beyond control did not cause sufficient variation between the mortalities in Troughs 17, 18, 19 and 20 to nullify the hypothesis that they formed a homogeneous group which might be considered as a whole. Although this does not hold true for some of the water conditions, it was felt that the best estimate of mortalities would still be obtained if trough pairs were combined. Further justification for pooling lots in like water types is the fact that mortalities significantly different from the control were always higher.

Table IV, shows the results after pooling the data of Table 8 from lots subjected to like types of water and converting the mortalities into cumulative percentages. The probability that the mortality in each water type was significantly different from the mortality in straight river water was again tested, using chi-square. The results were essentially the same as when the lots were considered individually, and those showing probable difference have been underlined. These data are shown graphically in Figure 4. The high mortality suffered by the fish in straight effluent water [2] (Troughs 1 and 2) during the first week (8-27 - 9-2) is largely due to the unusual water conditions which existed during the evening of August 31, 1945 and referred to in the section above. Rather consistent daily mortalities in this group in subsequent weeks maintained a high death rate throughout most of the test. Although the statistical test indicates that the mortalities in most of the other experimental groups were also significantly higher than that of the control, the sequence in which they occur would indicate that factors other than the concentration of effluent water were responsible for the differences. Thus, next in order of magnitude to the straight effluent lot referred to above, the highest mortality occurred in Troughs 11 and 12, which have a water type of 1:250. On the other hand, the mortality in Troughs 7 and 8, at a concentration of 1:50, is not significant from that of the controls. This would lead one to the conclusion that the straight effluent water caused a very great increase in mortality among the steelhead trout, but that dilutions of the effluent of 1:50 or more caused insignificant increases in the mortality, the other differences being due to factors beyond control: i.e., disease. The fact that the mortality among the fish held in refrigerated effluent water was relatively lower than in many of the high dilutions is of interest. During this preliminary period the temperature of the refrigerated water was about 13°C., somewhat lower than that of the river water.

(1) A discussion of the statistical methods used is beyond the scope of this report. For methods of calculation, the reader is referred to textbooks or to "Statistical Methods at H.E.W.", B. F. Butler to File, Aug. 6,1946.

(2) Actually the water is partially cooled in the precooling coils. In the tables, figures, and in this discussion it is referred to merely as effluent to avoid confusion with the effluent cooled by refrigeration.

 [redacted]

TABLE IV

MORTALITIES OF STEELHEAD TROUT FINGERLINGS HELD IN PRELIMINARY CONCENTRATIONS OF AREA EFFLUENT WATER

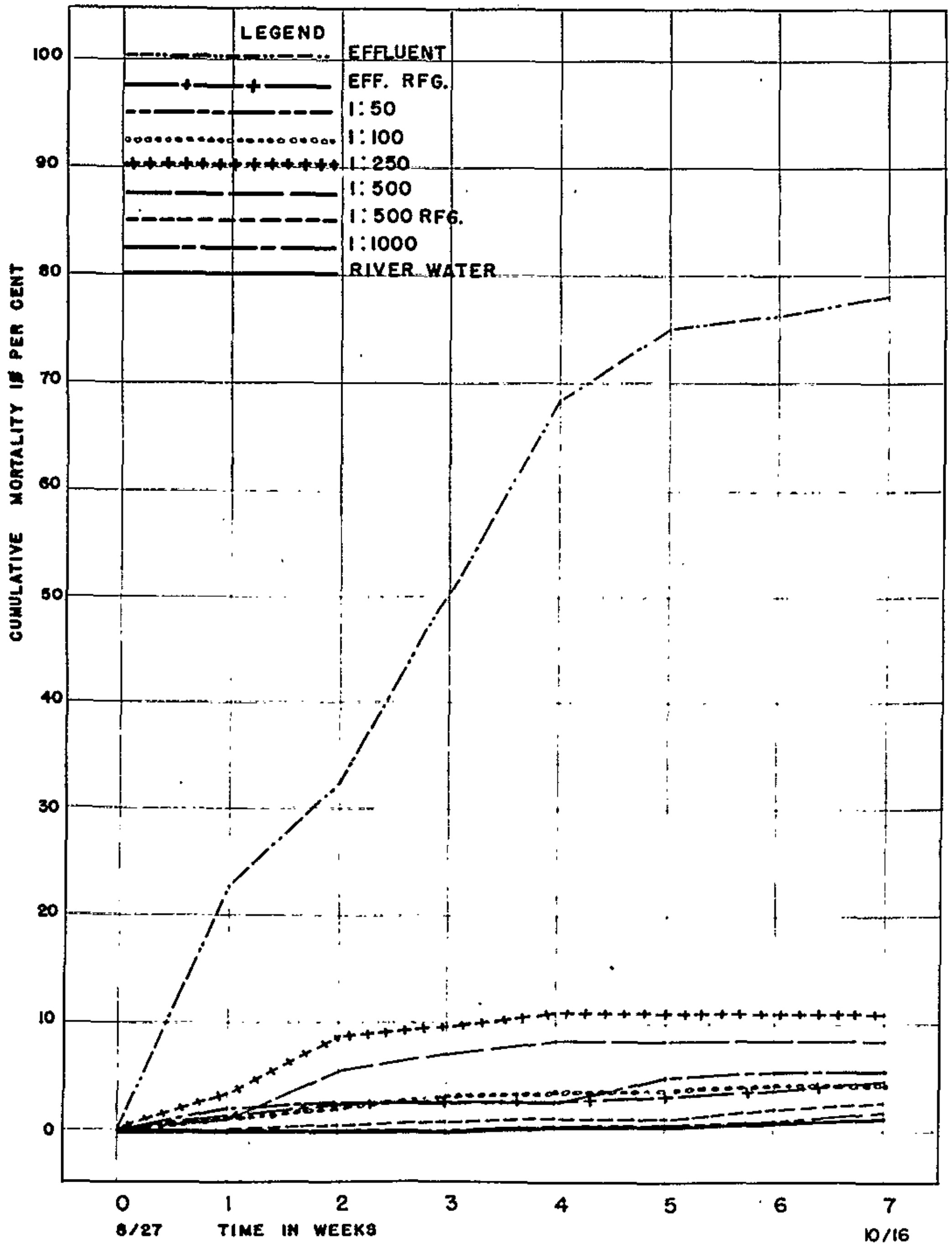
Type of Water		Effluent		Refrigerated Effluent		1:500 Refrig.Eff.		1:50		1:100		1:250		1:500		1:1000		River Water	
Lot Nos.		1 & 2X		3X & 4		5 & 6		7 & 8		9 & 10		11 & 12		13 & 14		15 & 16		17,18,19,20	
No. of Fish		252		214		224		210		236		236		261		272		431	
Week	Date	Mort	Cum%	Mort	Cum%	Mort	Cum%	Mort	Cum%	Mort	Cum%	Mort	Cum%	Mort	Cum%	Mort	Cum%	Mort	Cum%
1	8/27-9/2	57	22.6	3	1.4		0.0		0.0	3	1.3	8	3.4	3	1.1	5	1.8		0.0
2	9/3-9/9	24	32.1	2	2.3	1	0.4		0.0	2	2.1	13	8.9	11	5.4	2	2.6		0.0
3	9/10-9/16	46	50.4	1	2.8	1	.9		0.0	3	3.4	2	9.7	5	7.3		2.6	2	0.5
4	9/17-9/23	46	68.6		2.8	1	1.3	1	.5	1	3.8	3	11.0	3	8.4		2.6		0.5
5	9/24-9/30	16	75.0	1	3.3		1.3		.5		3.8		11.0		8.4	7	5.1		0.5
6	10/1-10/7	3	76.2	1	3.7	2	2.2	1	1.0	1	4.2		11.0		8.4	1	5.5	1	0.7
7	10/8-10/14	5	78.2	2	4.7	1	2.7	2	1.9		4.2		11.0		8.4		5.5	2	1.2
Total		197		10		6		4		10		26		22		15		5	

FIGURE 4

MORTALITIES OF STEELHEAD TROUT FINGERLINGS

HELD IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER

PRELIMINARY CONDITIONS



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The data in appendix Table 9 have been similarly treated and combined. Table V and Figure 5 show the results of pooling the mortalities of the various lots into groups subjected to similar water conditions. The unusually adverse conditions (probably "Calol") which existed in the effluent water on October 11, and October 16, caused the extremely heavy mortalities during the first week in the effluent, refrigerated effluent, and the 1:3 groups. What is probably a continuation of this effect is seen in the 1:3 group during the second week and in the refrigerated effluent water group up to the fourth week. Subsequent mortalities in these groups were practically nil. Mortalities in all other water concentrations and in the controls were practically nil throughout this final period.

Growth in Length

The fish were measured every four weeks, and the results obtained are shown as frequencies in appendix Tables 10, 11, 12, 13, 14 and 15. These data are sufficiently consistent to permit pooling of lengths of fish in lots subjected to similar water conditions. This is indicated by the fact that at no time did the average length of any of the control lots differ significantly from that of the group as a whole. The average lengths for the pooled lots for both the preliminary and final parts of the experiment are given in Table VI. Values which are underlined are significantly higher or lower than those for the control group in straight river water, as indicated by the "t-test", those underlined with dots are of questionable significance. These data are presented graphically in Figure 6.

The lots were not all of uniform length when first measured on August 15-16, 1945, but the differences were relatively small and did not materially alter the final relationships. The growth of the fish in length was clearly and significantly retarded in cases where they were held in undiluted effluent water; however, during the first two months, the increase in length was much better in refrigerated effluent water than in effluent water which was only partially cooled. The curve for the fish held in refrigerated effluent water is interrupted at the end of the second month, October 9-10, 1945, since this marks the termination of the first part and the beginning of the final part of the experiment. At this time the original stocks of fish in Troughs 3 and 4 were practically all dead, and new stocks were introduced. Also at this time the 1:500 (refrigerated effluent) and the 1:100 concentrations were discontinued and the 1:3 and 1:10 concentrations started. The two groups which were discontinued are not shown on Figure 6 to avoid confusion.

Following the adverse water conditions of October 11 and 16, 1945, the growth in length of the fish in Troughs 1-6, that is, in the effluent, refrigerated effluent, and 1:3 water types, was clearly retarded, but increased again during the subsequent two months. The fish in the 1:3 concentration actually grew at a faster rate than the controls and were approaching a significantly greater length at the end of the test. The fish in the 1:10, 1:50, and 1:250 concentrations were significantly longer than the control fish at the end of the test, the difference beginning to appear in November. This is possibly due to the fact that the higher concentrations of effluent water were warmer than the river water and encouraged faster growth. The rate of growth in nearly all lots was a bit slower during December, probably because of colder temperatures of the Columbia River water.

 [redacted]

TABLE V

MORTALITIES OF STEELHEAD TROUT FINGERLINGS HELD IN THE FINAL CONCENTRATIONS OF AREA EFFLUENT WATER

Type of Water		Effluent		Refrigerated Effluent		1:3		1:10		1:50		1:250		1:500		1:1000		River Water	
Lot Nos.		1A & 2A		3 & 4		5A & 6A		7A & 8A		9A & 10A		11 & 12		13 & 14		15 & 16		17,18,19,20	
No. of Fish		98		100		100		100		100		100		100		100		200	
Week	Date	Mort	Cum%	Mort	Cum%	Mort	Cum%	Mort	Cum%	Mort	Cum%	Mort	Cum%	Mort	Cum%	Mort	Cum%	Mort	Cum%
1	10/12-10/18	80	81.6	98	98	51	51		0		0		0		0		0		0
2	10/19-10/25	1	82.7		98	11	62		0	1	1		0		0		0		0
3	10/26-11/1	2	84.7		98		62		0		1		0		0		0	1	0.5
4	11/2-11/8	3	87.8		98		62		0		1		0		0		0	1	1.0
5	11/9-11/15		87.8		98	1	63		0		1		0		0		0	1	1.5
6	11/16-11/22	1	88.8		98	1	64		0		1		0		0		0	2	2.5
7	11/23-11/29		86.8		98		64		0		1		0		0		0		2.5
8	11/30-12/6		88.8		98		64		0		1		0		0		0	1	3.0
9	12/7-12/13		88.8		98		64		0		1		0		0		0		3.0
10	12/14-12/20		88.8		98		64		0		1		0		0		0		3.0
11	12/21-12/27		88.8		98	1	65		0		1		0		0		0		3.0
12	12/28-12/31		88.8		98		65		0		1		0	1	1		0		3.0

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FIGURE 5

MORTALITIES OF STEELHEAD TROUT FINGERLINGS

HELD IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER

FINAL CONDITIONS

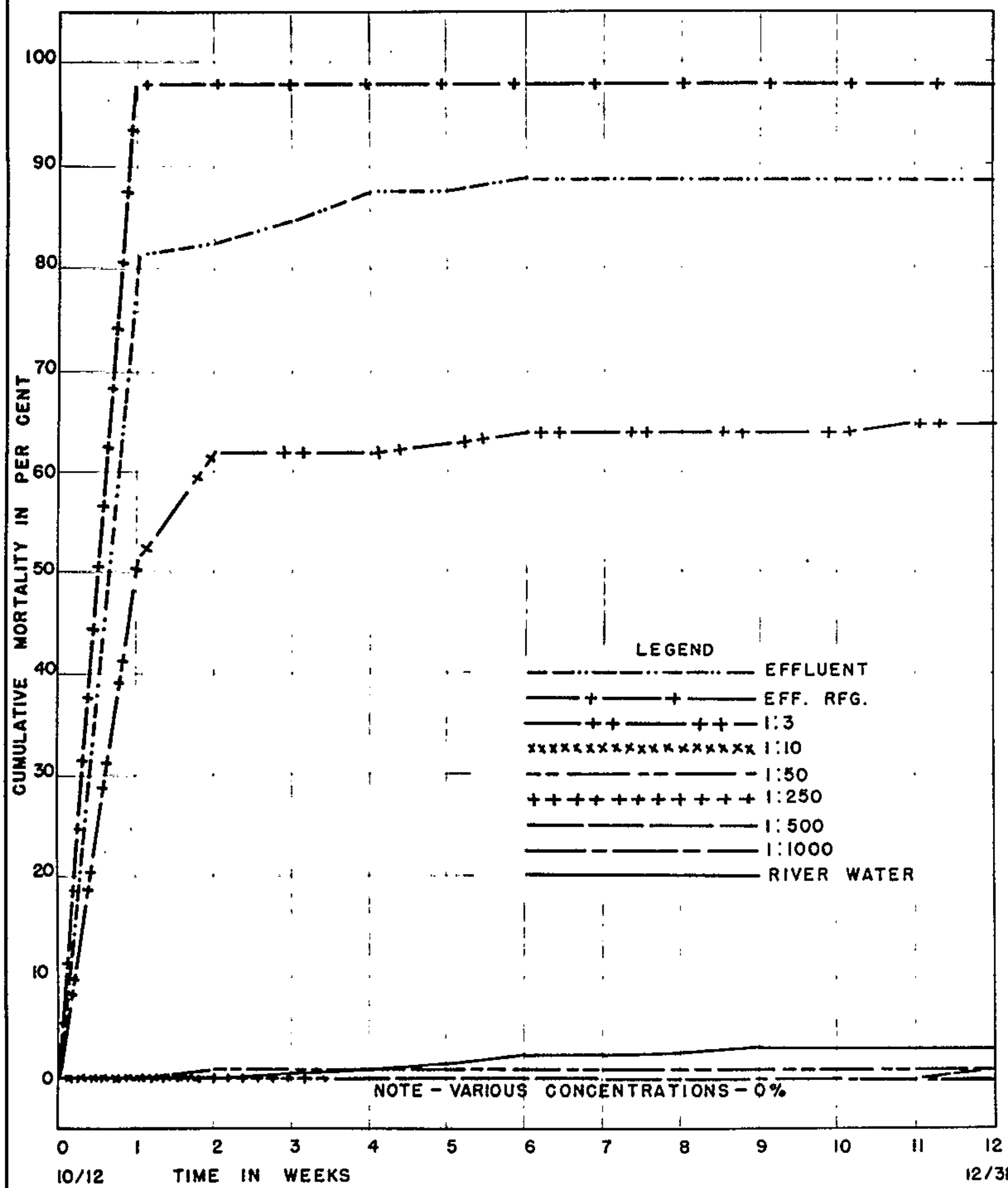

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TABLE VI

AVERAGE LENGTH IN MM OF STEELHEAD TROUT HELD IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER

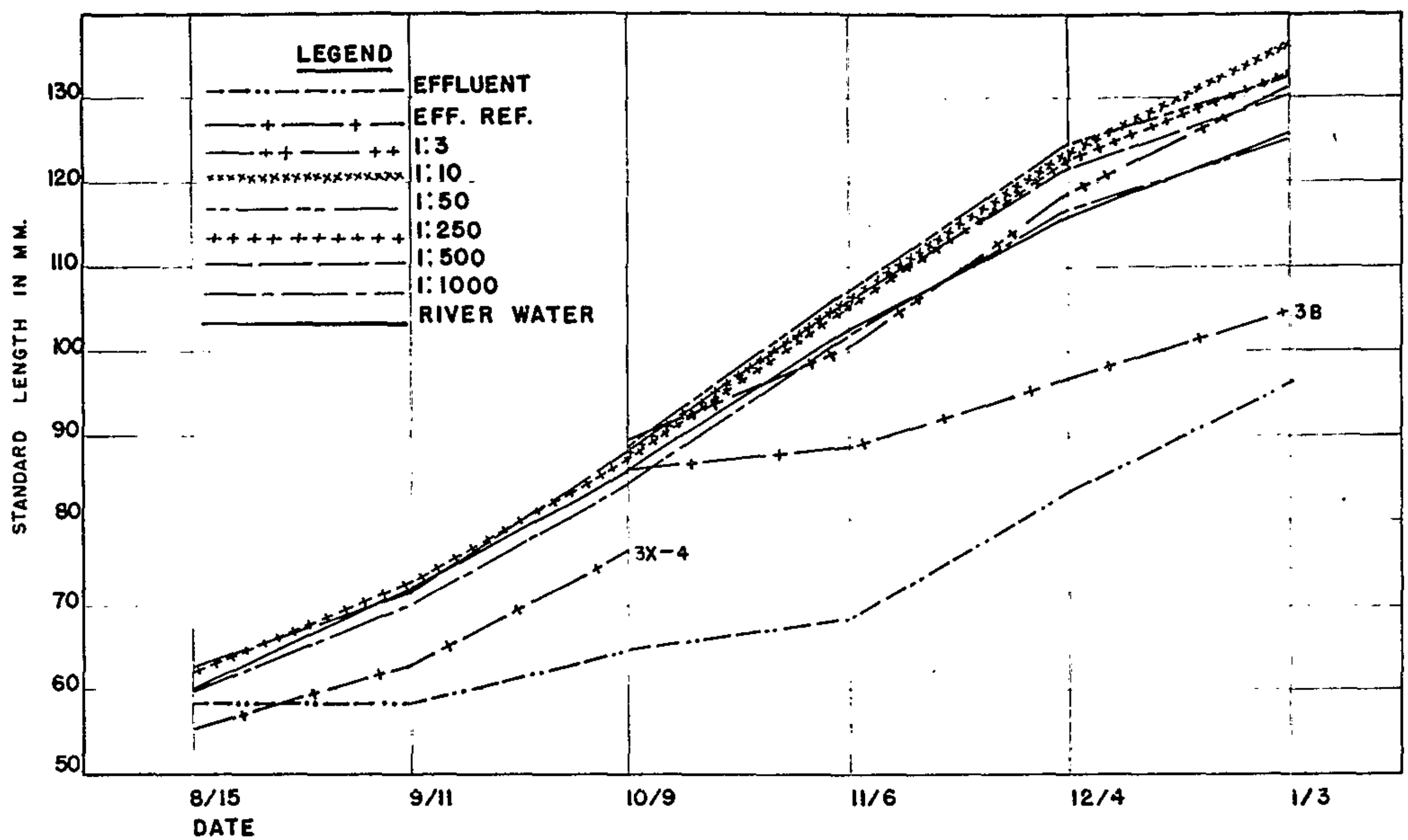
Type of Water	Effluent	Refrigerated Effluent	1:500 Refrig.Eff.	1:3	1:10	1:50	1:100	1:250	1:500	1:1000	River Water
Preliminary Lot Nos.	1 & 2X	3X & 4	5 & 6			7 & 8	9 & 10	11 & 12	13 & 14	15 & 16	17,18,19,20
Aug. 15-16	58.40	55.55	61.05			60.15	60.20	62.15	62.50	59.55	59.85
Sept. 10-13	58.40	62.9	71.75			71.41	73.42	72.75	71.65	70.00	71.78
Oct. 9-10	64.69	76.15	89.60			87.50	87.75	87.45	89.31	84.45	85.87
Final Lot Nos.	1A	3B		5A & 6A	7A & 8A	9A & 10A		11 & 12	13 & 14	15 & 16	17,18,19,20
Oct. 9-10	64.69	85.87		89.60	87.75	87.50		87.45	89.31	84.45	85.87
Nov. 6	68.50	88.85		100.52	106.31	106.75		106.36	105.95	101.86	101.80
Dec. 4	82.78	96.79		118.89	123.61	123.97		123.38	121.87	117.08	115.96
Jan. 1-5	96.25	104.64		131.14	136.28	132.07		132.47	130.51	125.26	125.70

9 2 1 2 1 7 3 0 4 9 7

FIGURE 6

GROWTH IN LENGTH OF STEELHEAD TROUT

HELD IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER



Growth in Weight

The fish were weighed every two weeks, and these results are tabulated in appendix Tables 16 and 17. Pooling the lots subjected to similar water conditions, as before, the average weights for the various water conditions are shown in Table VII, Part (A), for the preliminary conditions and Part (B) for the final conditions. These data are presented graphically in Figure 7. Since the fish were first weighed on July 30, Figure 7 begins at an earlier date than does Figure 6, and thus shows more uniformity among the various groups at the start. As might be expected, Figures 6 and 7 show almost identical results; Figure 7 is, however, more readily interpreted since weights increase approximately as the cube of the length, and thus size differences are expanded; further, the fish were weighed twice as often as they were measured, which results in twice the number of points in the curves of Figure 7.

Increase in weight was markedly retarded in both effluent and refrigerated effluent water and was actually stopped for about two weeks following the particularly adverse water conditions on October 11 and 16, 1945. Aside from a brief retardation in the fish subjected to the 1:3 dilution immediately following the adverse conditions of October 11 and 16, the growth of the fish in dilutions of the effluent water was not inhibited. Rather, there is an appreciable increase in growth rate among the fish held in the higher dilution, which is probably the result of higher water temperatures.

It is extremely difficult to show a significant difference between the average weights of the various groups by statistical methods. This is due to the fact that the fish of each lot were weighed as a group. This variability is, however, adequately brought out by the lengths when each fish was measured individually. As a verification of the hypothesis that groups differing significantly from the control in length also differed significantly in weight, each fish was weighed individually at the termination of the experiment. The last line of Table VII, Part (B), shows the arithmetic means of the weights obtained by this method. The mean for each water type was compared with that of the river water control group by the "t-test", and values which were probably significantly higher or lower were underlined. Comparison of these significant weights with the significant lengths for January 1-5 in Table VI shows near perfect agreement. The test appears somewhat more sensitive with the weights than with the lengths: for example, the average length of the fish in the 1:3 was only questionably significant (between the .05 and .01 limit of probability), while the average weight of this group was definitely significant (beyond the .01 limit). Similarly, in the 1:500 group, the length was not significant from that of the control, although it had been the previous month, while the weight of this group was possibly significantly different.

Discussion

The early part of the steelhead trout experiment was subject to the same difficulties in control of equipment and water conditions as were encountered in the chinook salmon pilot experiment, but again one of the chief purposes of the test, that of perfecting the equipment, was satisfactorily accomplished. Serious disease epidemics also existed among the trout during the early part of the experiment, but were not as severe as in the salmon,

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TABLE VII

AVERAGE WEIGHT IN GRAMS OF STEELHEAD TROUT HELD IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER

(A) Preliminary Conditions

Type of Water	Effluent	Refrigerated Effluent	1:500 Refrig.Eff.	1:50	1:100	1:250	1:500	1:1000	River Water
Lot Nos.	1 & 2X	3X & 4	5 & 6	7 & 8	9 & 10	11 & 12	13 & 14	15 & 16	17,18,19,20
7/30/45			3.30	3.25	3.36	3.29	3.24	3.02	3.30
8/13/45			4.13	3.90	4.21	4.19	4.05	3.80	3.85
8/27/45	3.95	3.93	5.28	4.94	5.49	5.42	5.44	5.12	5.08
9/10/45	3.68	4.53	7.06	6.66	7.31	7.17	7.07	6.79	6.92
9/24/45	3.87	5.51	8.89	8.45	9.25	8.92	8.77	8.46	8.64
10/8/45	4.79	7.60	12.79	11.97	13.17	12.71	12.44	11.17	12.22

(B) Final Conditions

Type of Water	Effluent	Refrigerated Effluent	1:3	1:10	1:50	1:250	1:500	1:1000	River Water
Lot Nos.	1A	3B	5A & 6A	7A & 8A	9A.&10A	11 & 12	13 & 14	15 & 16	17,18,19,20
10/8/45	4.79		12.79	13.17	11.97	12.71	12.44	11.17	12.22
10/22/45	4.80	11.50	15.25	17.18	17.70	17.48	18.29	16.05	16.19
11/5/45	6.00	11.86	20.74	22.99	22.71	22.81	22.77	20.03	20.06
11/19/45	7.20	14.14	26.81	28.45	27.06	27.02	26.63	23.42	23.95
12/3/45	10.44	16.28	33.42	36.40	33.35	33.52	32.63	28.68	28.37
12/17/45	13.78	19.33	39.78	41.51	37.47	36.36	35.44	32.40	32.40
12/31/45	13.11	20.71	46.60	45.36	40.68	39.70	38.80	35.05	35.03
12/31 to 1/5/46 individuals	16.00	19.93	46.03	46.10	39.15	38.91	38.27	33.49	34.05

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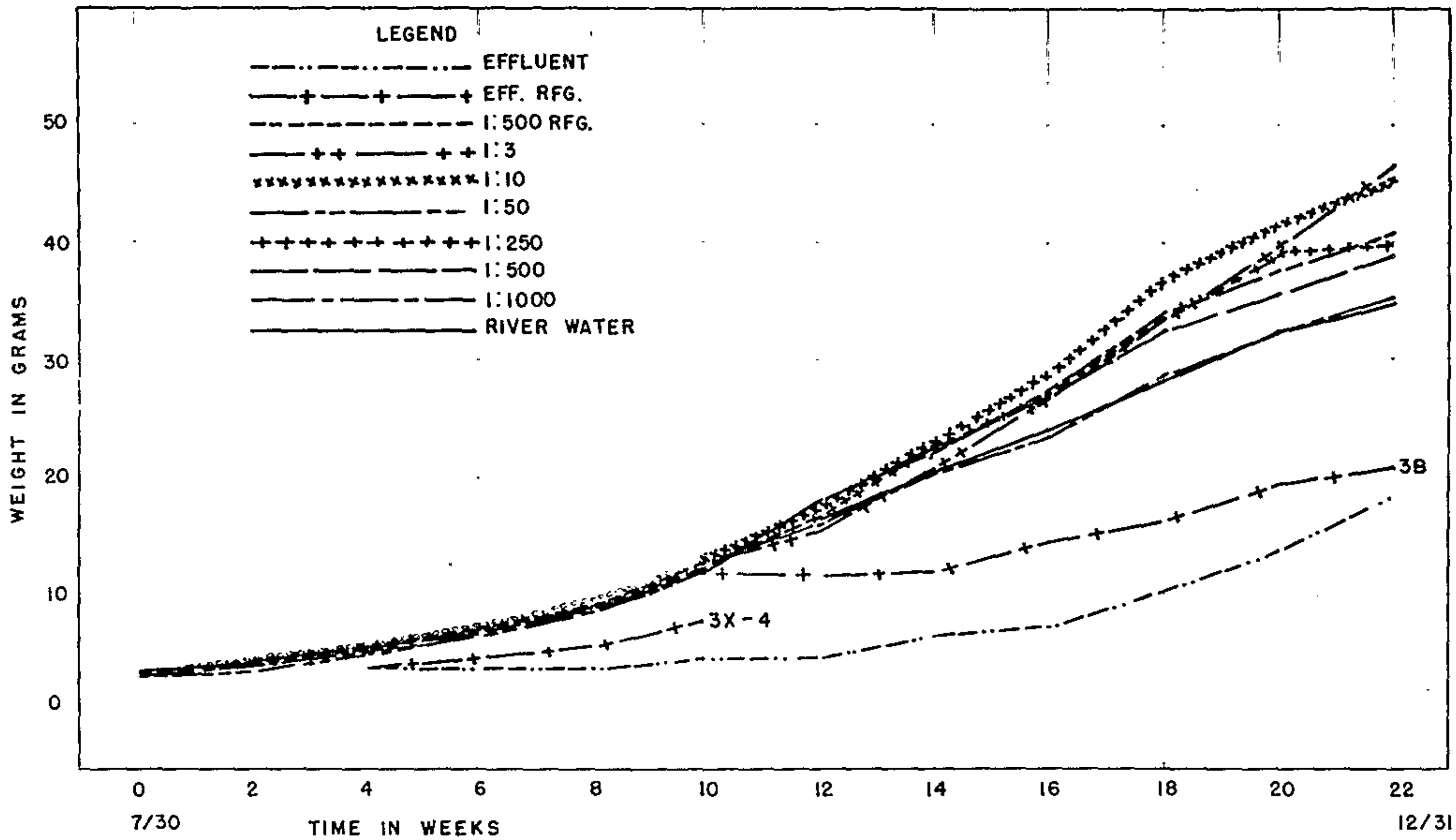
FIGURE 7

GROWTH IN WEIGHT OF STEELHEAD TROUT

HELD IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER



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and repeated treatments brought them under control. By the latter part of August, 1945, disease and the regulation of water conditions were sufficiently improved to conduct an experiment under reasonable control. Between August 27, and October 11, the dilutions of effluent water originally specified were used. On October 11 the number of fish in each trough was reduced to prevent overcrowding, and dilution levels of 1:3 and 1:10 were substituted for the 1:500 (effluent refrigerated) and 1:100 dilution levels previously used. No further changes in design were made.

The presence of some factor (probably "Calol") in the effluent water to which the trout were very sensitive caused a heavy mortality among the fish in Troughs 1 and 2 during the evening of August 31, and among the fish in Troughs 1, 2, 3, 4, 5 and 6 (effluent, refrigerated effluent, and one part effluent to three parts river water) on and immediately following October 11 and again on and following October 16. Consistently high mortalities persisted throughout most of the experiment in Troughs 1 and 2 (undiluted and unrefrigerated effluent water). Aside from these incidences, which were very pronounced, increases in mortality could not be attributable to the presence of area effluent water.

The rate of growth of the trout was markedly retarded in undiluted area effluent water, whether it was refrigerated or only partially cooled. The presence of "Calol" or some other adverse factor in the effluent water on October 11 and 16 further retarded the growth of these groups and in addition temporarily slowed the growth of the fish in the 1:3 dilution. No other incidence of retarded growth occurred among trout held in dilutions of the area effluent water; rather in the 1:3, 1:10, 1:50, 1:250, and possibly the 1:500 dilutions the fish actually grew somewhat faster than in straight river water. This increase in growth among the fish held in the higher concentrations of area effluent water was probably because of higher water temperatures in these troughs.

STUDIES ON CHINOOK SALMON EGGS AND YOUNG

Purpose

At the present time the chinook salmon are the most economically important fish inhabiting the upper Columbia River, this species making up the greater part of the salmon caught by fisherman of the lower Columbia River and by Indians fishing above Bonneville Dam. Chinook salmon select riffle areas for spawning, which are similar to many which exist in the Columbia River within and below the H.E.W. Reservation. Extensive spawning areas, which have been used by chinook salmon in the past, are present in the vicinity of White Bluffs. An important part of the studies at the Fish Laboratory was, then, to determine what effect the area effluent water might have on the developing eggs and young of chinook salmon. These stages were of particular importance since the eggs and newly hatched fish or "fry" occur in the gravel beds and thus are not capable of swimming away from adverse conditions, as older fish may do.

The development stages of the eggs and young fish studied in the laboratory were to parallel those under natural conditions in the river, and ultimately the fish reared in the laboratory were to be liberated at a time when they would normally migrate to the ocean. This experiment was expected to furnish the most significant and usable results.

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Origin of the Eggs

It was not feasible to capture sexually mature chinook salmon on spawning grounds of the upper Columbia River for a source of eggs. The eggs used in this experiment were, therefore, obtained from a stock entering Green River, a tributary to Puget Sound, and intercepted by the State of Washington, Department of Fisheries at Soos Creek. The progeny of chinook salmon from Green River could be expected to react to the various concentrations of the area effluent water in the same manner as progeny from Columbia River chinook salmon. The eggs were readily obtainable at the Soos Creek Hatchery, and in addition expected rates of survival and growth were known for this stock.

Late in October, the temperature of the Columbia River had fallen to about 14°C., a level suitable for the incubation of chinook salmon eggs. On the morning of October 24, 1945, L. R. Donaldson and A. D. Welander of the University of Washington selected eight mature female chinook salmon from the stock available at the Soos Creek Hatchery. The eggs were removed from these fish, fertilized, and immediately transported by car to the Fish Laboratory. On arrival, at 5:30 p. m. of the same day, the 45,800 eggs obtained were tempered with river water for about one hour and then distributed approximately equally among forty trays, there being two trays in each trough. To further avoid any temperature shock which might result from placing the eggs in water of a warmer temperature, river water only was run into Troughs 1, 2, 5, 6, 7 and 8 at the time the eggs were placed on the trays in these troughs. Later, area effluent water was gradually turned back in so that there was a gradual temperature rise to the operating level.

On arrival at the Fish Laboratory there was a small area in the center of each transportation basket which contained a number of eggs killed in transit. Generally, however, the eggs were in good condition.

Experience and Condition

The Eggs

During their incubation period the eggs were held in shallow trays with wooden frames and plastic screen bottoms. Two such trays were wedged near the surface in the upper part of each trough, and baffles were installed to insure water circulation through the eggs. The lower parts of the same troughs were used for the steelhead trout experiment described above. A lot number was assigned to each tray of eggs, which corresponded to the trough number, and in addition contained the suffix "A", denoting the upper, or "B" the lower tray of the pair.

Since some loss was experienced from transporting the eggs, as could reasonably be expected, all obviously dead or injured eggs were removed from the trays on the morning of October 25. The number removed from each trough was recorded, but this loss was not included in subsequent mortality data. In general, the initial loss or "pick-off" was less than 10 per cent.

The water conditions used during this experiment were the same as those maintained during the later part of the trout studies, namely:

 [redacted]

TROUGH NO.	WATER TYPE	RATE OF FLOW
1 & 2	100% area effluent water, partially cooled (4° to 5°C. warmer than river water)	3 g.p.m.
3 & 4	100% area effluent water, refrigerated to river water temperature	3 g.p.m.
5 & 6	1:3 effluent to river water	5 g.p.m.
7 & 8	1:10	5 g.p.m.
9 & 10	1:50	5 g.p.m.
11 & 12	1:250	5 g.p.m.
13 & 14	1:500	5 g.p.m.
15 & 16	1:1000	5 g.p.m.
17 & 18	100% river water	5 g.p.m.
19 & 20	100% river water	3 g.p.m.

On October 26 the dead eggs were again removed from all of the trays, and these mortalities were the first recorded as occurring under the experimental conditions. During the next three weeks the eggs were developing through states which are very delicate and easily injured. During this period, therefore, they were handled as infrequently and as gently as possible. Frequent removal of dead eggs from Troughs 1, 2, 5 and 6 was necessary, however, since extremely heavy mortalities persisted in these lots and had the dead eggs been left in the trays, entire groups would have been spoiled. Silt from the river water and ferric sulphate sludge from the effluent water accumulated on the eggs and occasionally had to be siphoned off to prevent the eggs from smothering.

By the second week in November, most of the eggs had developed to what is known as the "eyed" stage. At this time the young embryo is clearly visible, and the eggs can withstand considerable handling without injury. None of the eggs held in Troughs 1, 2, 5 or 6, where temperatures were 4° to 5°C. warmer than the river water, developed to the "eyed" stage.

In order to further test the effect of the water conditions in Troughs 1, 2, 5 and 6 on developing eggs, a second batch was brought to the laboratory from the Soos Creek Hatchery. These replacement eggs were from the same stock of chinook salmon as those used originally and had developed to an "eyed" stage comparable with that of the eggs in straight Columbia River water. New lot numbers were assigned to these replacement eggs; the number again corresponded to that of the trough, but suffixes "C" and "D" were used to identify the new trays.

Nearly all of the eggs hatched during the first two weeks of December. Those which were incubated in the warmest water, that is, Troughs 1, 2, 5, 6, 7 and 8 were the first to hatch. Those incubated in river and refrigerated effluent water were the last to hatch.

<u>The Fry</u>

When first hatched, the young salmon or "fry" are nourished by a yolk sac which is incorporated into the ventral body wall. In water temperatures of 6° to 9°C., this yolk is used up in about six weeks or two months, and at the end of this time, the young fish are ready to start feeding.

In each trough the fry which hatched from the upper tray (A) and the lower tray (B) were combined into a single lot with a number corresponding to that of the trough. A suffix "r" was added to the lot numbers of those in Troughs 1, 2, 5 and 6 to show that the original egg lots had been reestablished.

During the latter part of December, the fry in the undiluted effluent water, Troughs 1 and 2, began to die in large numbers. Shortly thereafter the mortality among the fry in the 1:3 dilution began to rise sharply. Considerably later, during the last week in January 1946, the fry mortality in the refrigerated effluent water also rose sharply. None of the fry in the undiluted effluent water, Troughs 1, 2, 3 or 4, survived long enough to completely absorb their yolk sacs and only a very few in the 1:3 dilution, Troughs 5 and 6, successfully reached the feeding stage. These fry in the first six troughs showed no indication of their imminent fate when first hatched. Soon, however, they began to appear weak and exhibited abnormal swimming actions. During the peak of mortality, and later, most of the individuals that died showed "white spot disease", characterized by precipitated particles in the yolk. "White spot" disease, however, is thought to be caused by adverse environmental conditions rather than disease organisms. Further, the development of the fry in the refrigerated effluent water was considerably slower than in straight river water of the same temperature. When the fish in the control lots had completely absorbed their yolks and were starting to feed, those in the refrigerated effluent water of Troughs 3 and 4 still retained a large amount of yolk and were smaller in size. Although the fry in the 1:3 dilution absorbed their yolk sacs at about the same rate as those in straight river water, their size at the end of the yolk sac stage was appreciably smaller than that of controls. The fry held in concentrations of 1:10 or less appeared and acted like those in straight river water.

Plates IV through XI show the relative appearance and size of fry selected from the various water conditions on February 18, 1946, at which time, most of the fish had just started to feed. The fish portrayed in Plates IV through VIII are very much alike. Those in Plate IX, representative of fry in 1:10 dilution, are of approximately the same length as those in the weaker concentrations of effluent water but have not eaten as much food recently and appear a little emaciated. The fish shown in Plate X taken from the 1:3 dilution, are in relatively good condition but are distinctly smaller in size than those in straight river water. Plate XI shows fry from refrigerated effluent water which, although apparently in good condition, are smaller in size and have not completely absorbed the yolk sac.

Plates XII through XIX were taken on February 20, 1946 and show the general appearance and density of the fish in the various troughs. Again the similarity between the fish held in Troughs 7 through 20 is brought out. Plate XVIII shows Lots 5r, 6r and 18, Lot 18 being temporarily held in Trough 6 [1] pending repainting of Trough 18 and Lot 6r being temporarily held in the lower part of Trough 5. This plate affords a quick comparison between the fish held in 1:3 dilution and those held in straight river water. The differences in numbers and size are evident. Plate XIX shows the few weak and dying fish which remain in Trough 3 and 4 supplied with refrigerated effluent water. The yolk sacs remaining on many of these fish can also be seen.

(1) The effluent water was turned off in Trough 6 during this temporary change.

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CHINOOK SALMON FRY HELD IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER
FEBRUARY 18, 1946

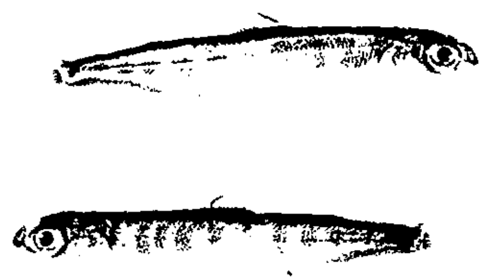

PLATE IV River Water

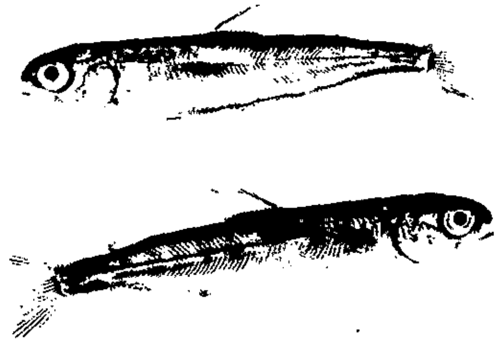

PLATE V 1:1000

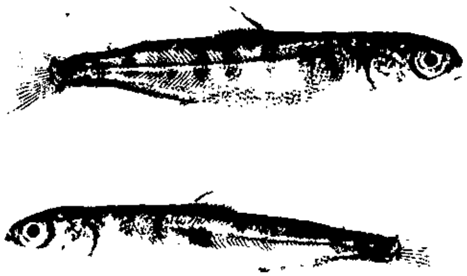

PLATE VI 1:500

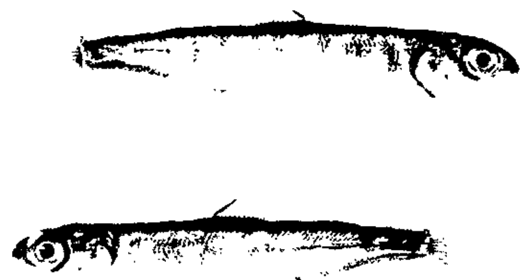

PLATE VII 1:250

9 2 1 2 7 9 1 5 9 5

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3

7 4759

CHINOOK SALMON FRY HELD IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER
FEBRUARY 18, 1946

7-4759 c.3 8/31/46

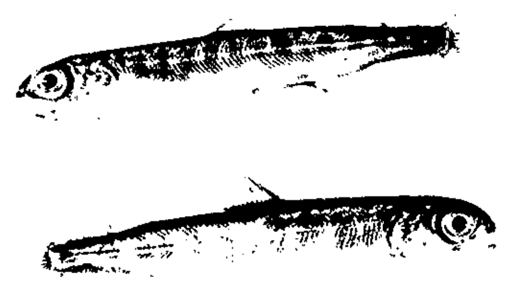

PLATE VIII 1:50

7-4759 c.3 8/31/46

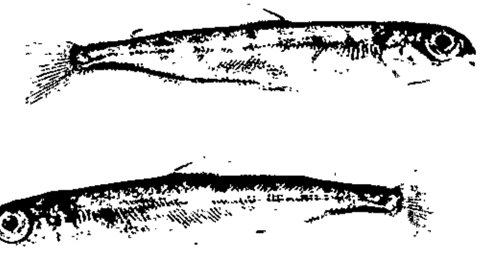

PLATE IX 1:10

7-4759 c.3 8/31/46

PLATE X 1:3

7-4759 c.3 8/31/46

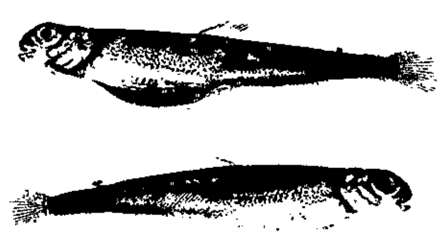

PLATE XI Refrigerated Effluent

[redacted]

[redacted] DECLASSIFIED [redacted] 3

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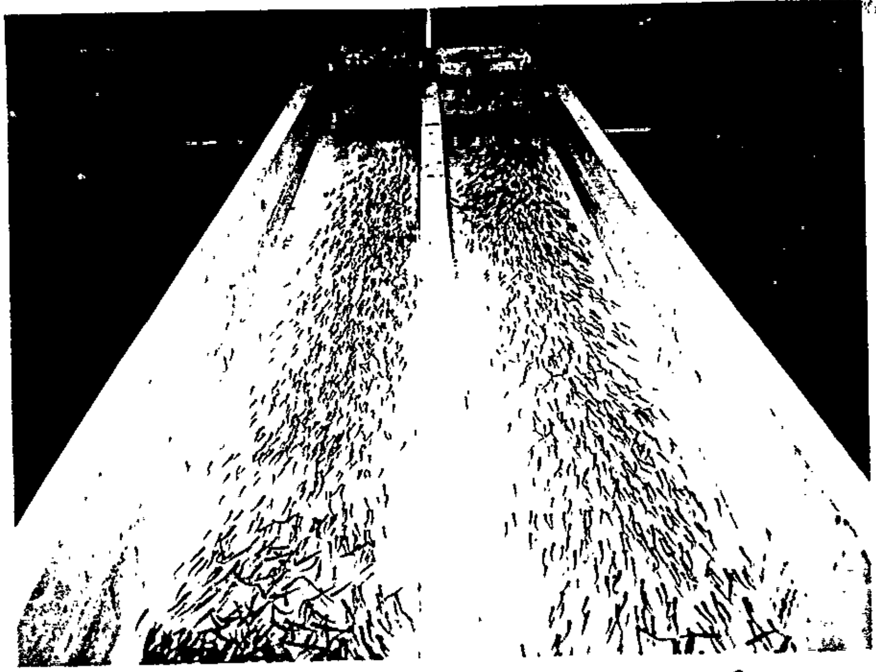
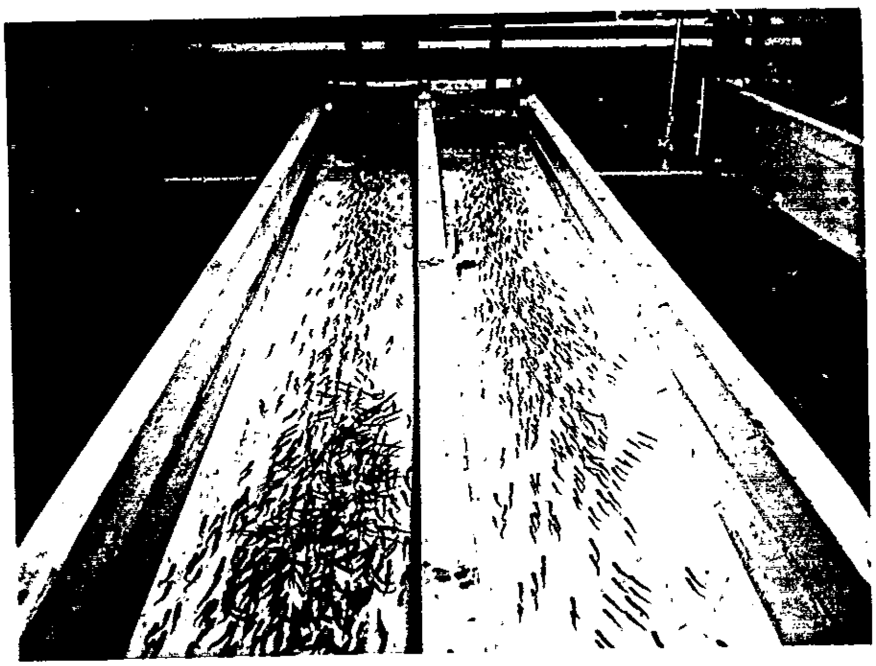


7-4759 C.3

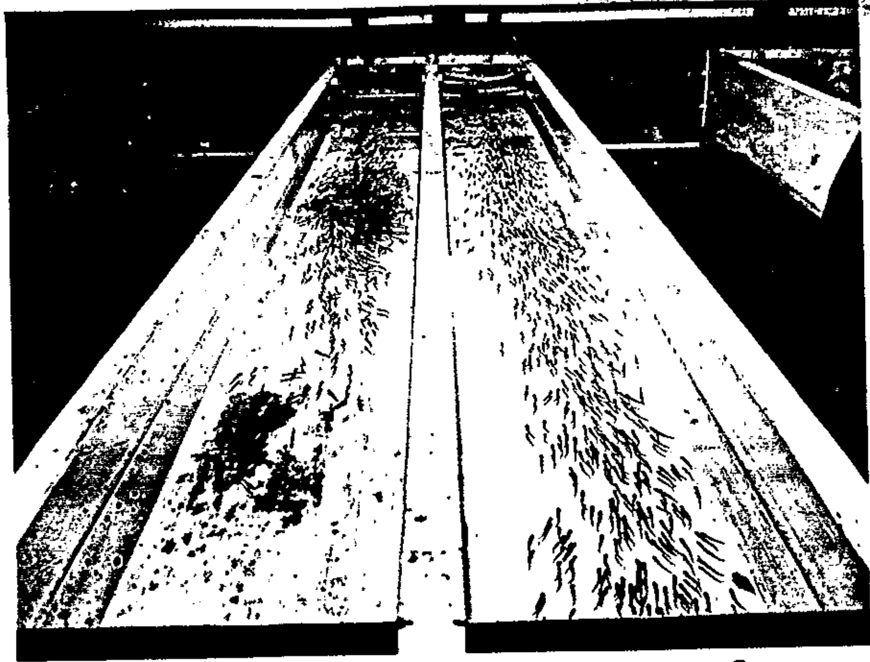
PLATE XII
Chinook Salmon Fry in Troughs 19 and 20
River Water Control 2-20-46



7-4751 C.3

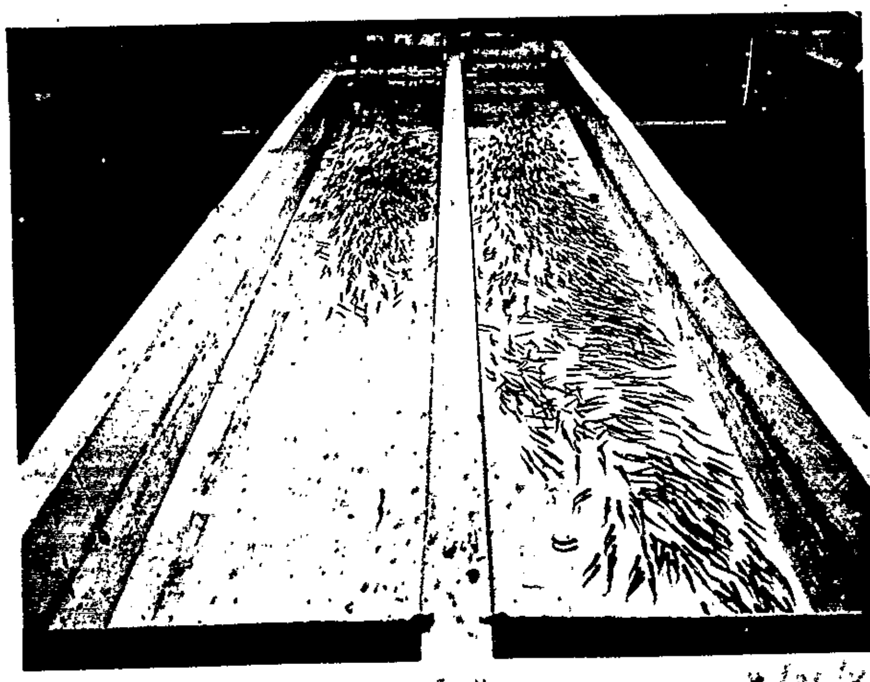
PLATE XIII
Chinook Salmon Fry in Troughs 15 and 16
1:1000 2-20-46

[redacted]



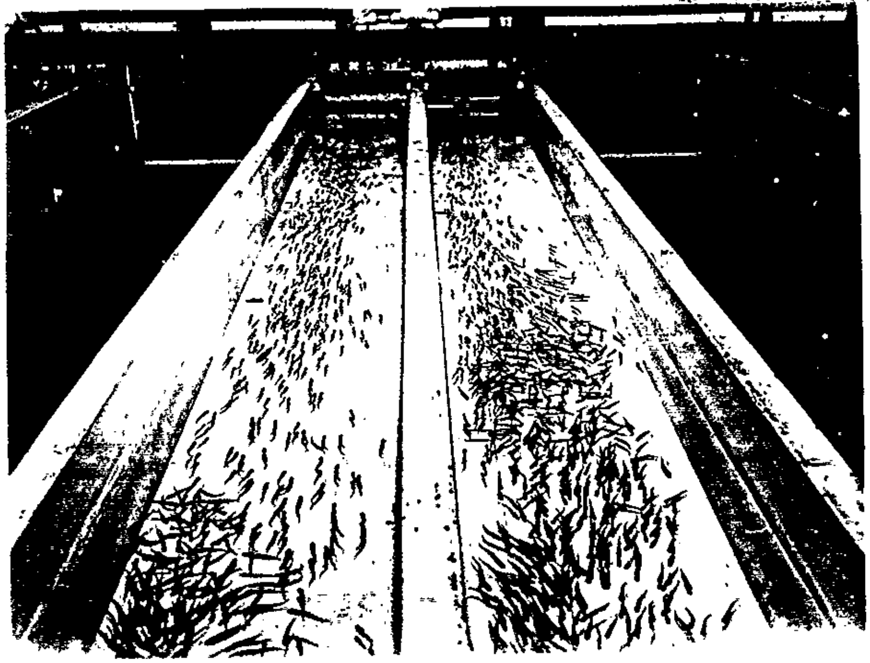
7-4751 C.3 9/31/46

PLATE XIV
CHINOOK SALMON FRY IN TROUGHS 13 and 14
1:500 2-20-46



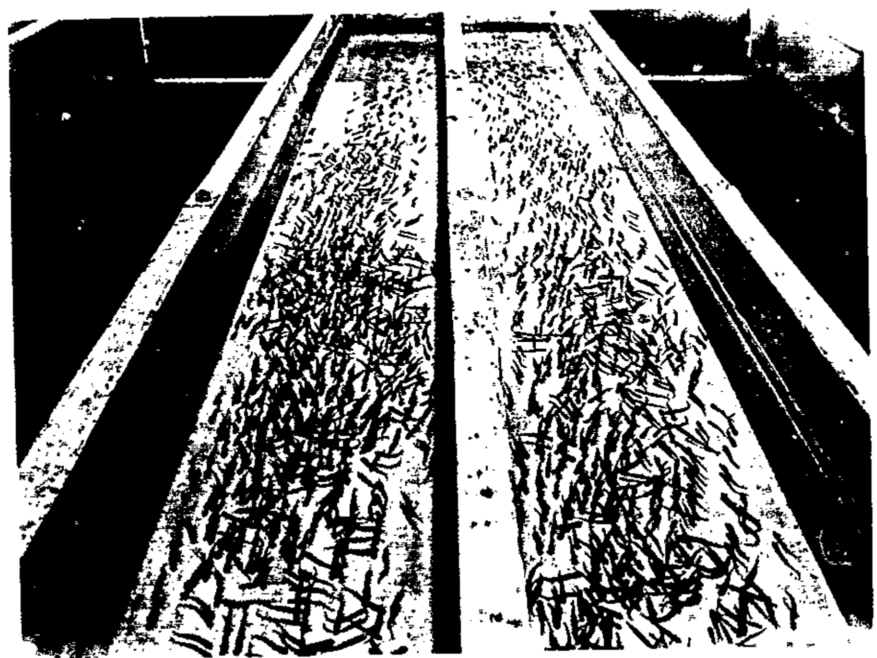
7-4751 C.3 9/31/46

PLATE XV
Chinook Salmon Fry in Troughs 11 and 12
1:250 2-20-46



7-4751 C.3 8/21/46

PLATE XVI
Chinook Salmon Fry in Troughs 9 and 10
1:50 2-20-46



7-4759 C.5 8.21.46

PLATE XVII
Chinook Salmon Fry in Troughs 7 and 8
1:10 2-20-46

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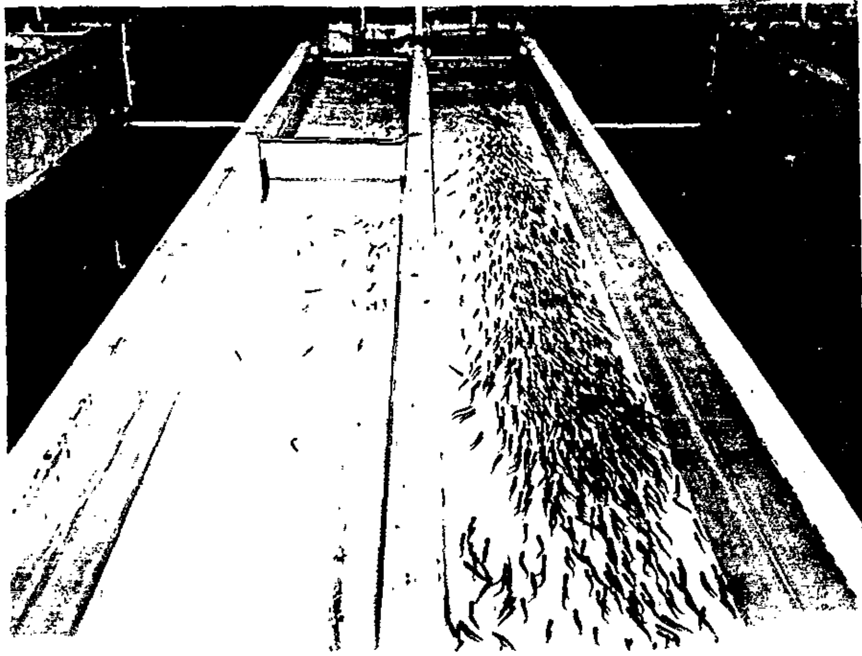

PLATE XVIII
Chinook Salmon Fry in Troughs 5 and 6
Lots 5r and 18
6r
1:3 and River Water 2-20-46

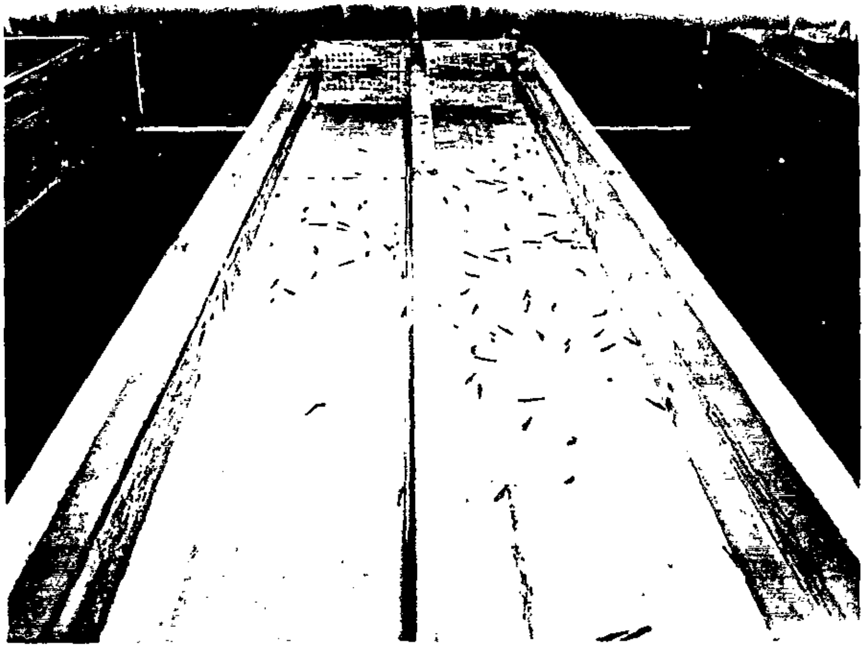

PLATE XIX
Chinook Salmon Fry in Troughs 3 and 4
Refrigerated Effluent Water 2-20-46

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The Fingerlings

After the young fish have completely absorbed their yolk sacs and are actively feeding they are called "fingerlings". Most of the fish reached this stage during the latter part of February, 1946. At this time the fish had increased in size to a point where it was no longer advisable to retain such large numbers of them in the troughs. Consequently, on February 27th, the number of fish in each trough was reduced to 500 and the surplus fish were planted in the Columbia River.

New lots of 500 fish each were established in Troughs 1, 2, 3, 4, 5 and 6 since none of the original fish remained in Troughs 1 and 2, only five remained in Troughs 5 and 6 and only 36 remained in Troughs 7 and 8. The fish used to establish these new lots were taken from the surplus resulting from the thinning out of the straight river water control lots. A suffix "A" was attached to the lot numbers of the new stocks in Troughs 1, 2, 3, 4, 5 and 6 to show that they were replacements and not derived from eggs hatched in these troughs. The few remaining fish from the original lots in Troughs 3, 4, 5 and 6 were not discarded, but were maintained as separate units until their death. The last fish of the original stocks in Troughs 3 and 4 died on March 7th. The sixteen fish of the original stocks in Troughs 5 and 6 remaining on March 15th, were unfortunately killed by accident when they were exposed to undiluted effluent water resulting from a brief outage of the river water supply. These few remaining fish of Lots 5r and 6r, were, on the other hand, very weak and emaciated and had never eaten food in proper amounts. Had they not been in such a weakened condition, they might well have survived the brief adverse conditions.

Although the fry in the 1:10 concentration had not died in such great numbers as those in the first six troughs, their mortality and condition was decidedly worse than that of fish in weaker concentrations of the effluent water. On February 27, 1946, when the number of fish in each lot was reduced, many of these fish in Troughs 7 and 8 were emaciated and subnormal. An infestation of an intestinal parasite, Octamitus, was found in these fish, but since it did not occur in appreciable amounts in any of the other lots, its presence was probably the result of a lower resistance among the fish of this group. The addition of a small amount of the drug "Carbarsone" to the diet soon eliminated the Octamitus, but this group of fish continued to suffer an excessive mortality and to contain undersize, emaciated fish up to the time the study was terminated. It was interesting to note, however, that this group also contained individuals which were the largest in the laboratory, such specimens had undoubtedly been able to overcome the adverse effect of the effluent water and take advantage of the warmer water temperature in these troughs. (See Table 27)

The fish in undiluted effluent water and in the 1:3 concentration suffered very heavy mortalities and poor growth throughout the experiment. Although these fish were frequently examined for parasites none, or very few, were ever found. Their general appearance in the trough, however, was not normal. During March, April and early May these fish showed evidence of irritated gills by holding their gill covers open, but microscopic examination showed no gill disease. The gill action gradually became more normal toward the end of the experiment. Many of the fish were emaciated and nearly all were somewhat listless. The presence of ferric sulfate sludge in the

[redacted]

water on Monday and Tuesday of each week seemed to increase the gill irritation and prevent the fish from feeding, but otherwise not to contribute to their discomfort. The fish which died were usually the weakest, most emaciated individuals, the stronger ones surviving the longest, which indicates a gradual and continual toxic or weakening effect of the effluent water rather than an occasional exceptionally adverse condition such as occurred during the steelhead trout experiment when large amounts of "Calol" were suspected of being present. The mortalities and growth of these and the other lots will be considered in more detail in sections immediately following.

From the latter part of May until the end of the studies a few of the fish in Troughs 7 through 20 suffered from "gas bubble" disease. This is probably an environmental disease caused by excessive gasses in the water and it also appeared on the chinook salmon fingerlings of the "pilot" test immediately after they were placed in river water at the Fish Laboratory during July, 1945. The gas blisters did not appear on the fish held in straight effluent water or in Troughs 5 and 6 where the volume of effluent water was great enough to appreciably dilute the amount of excess dissolved gases in the river water.

Plates XX to XXIX show the general appearance of the fish in the various trough pairs on July 2, 1946. Plates XXIX and XXVIII show the very few small fish remaining alive in Troughs 1, 2, 3 and 4 at this time. The numbers and size of the fish in Troughs 5 and 6, Plate XXVII, are also greatly reduced. Plate XXVI shows the relatively fewer fish remaining in the 1:10 concentration and also the great variability in size of various individuals. The fish in the other trough pairs appear much alike, several "pop eyed" fish which are suffering from "gas bubble" disease may be seen in these lots.

By the end of June, 1946, these chinook salmon fingerlings had reached a size and age at which they would normally migrate downstream to the ocean. To retain them longer in the laboratory would introduce several uncontrolled factors which would tend to obscure the effect of the effluent water. Therefore, the experiment was terminated on July 3, 1946 and on July 5th the surviving 5,832 fish were liberated into the Columbia River adjacent to the 100-F Area.

Throughout this experiment the desired water conditions were maintained within the tolerance limits given on Page 13, which were reasonably strict. Only on rare occasions and then for brief periods of time was it necessary to alter them because of equipment failure.

Mortalities

Eggs

All salmon eggs which were obviously dead or not developing were removed from the trays in the various troughs as often as necessary and a record was kept of the removals. The date on which an egg was removed did not necessarily correspond to the time at which it died or stopped developing since many eggs which are wholly infertile or scarcely developed are not distinguishable for several weeks. Therefore, nearly all of the eggs which were removed were cleared in salt solution and fixed with acetic acid so that

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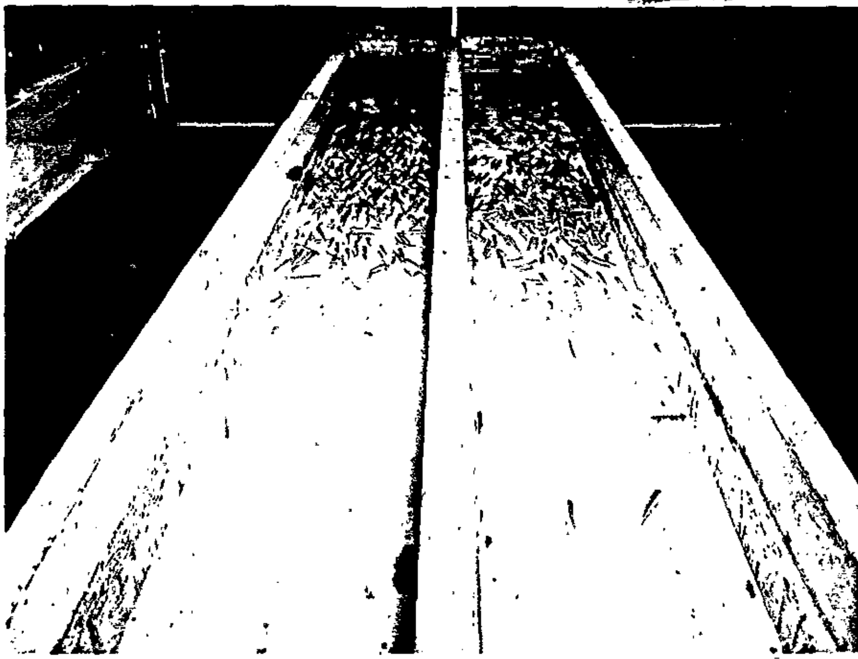

7-4757 C.3 7/31/46

PLATE XX
Chinook Salmon Fingerlings in Troughs 19 and 20
River Water Control 7-2-46

7-4757 C.3 7/31/46

PLATE XXI
Chinook Salmon Fingerlings in Troughs 17 and 18
River Water Control 7-2-46

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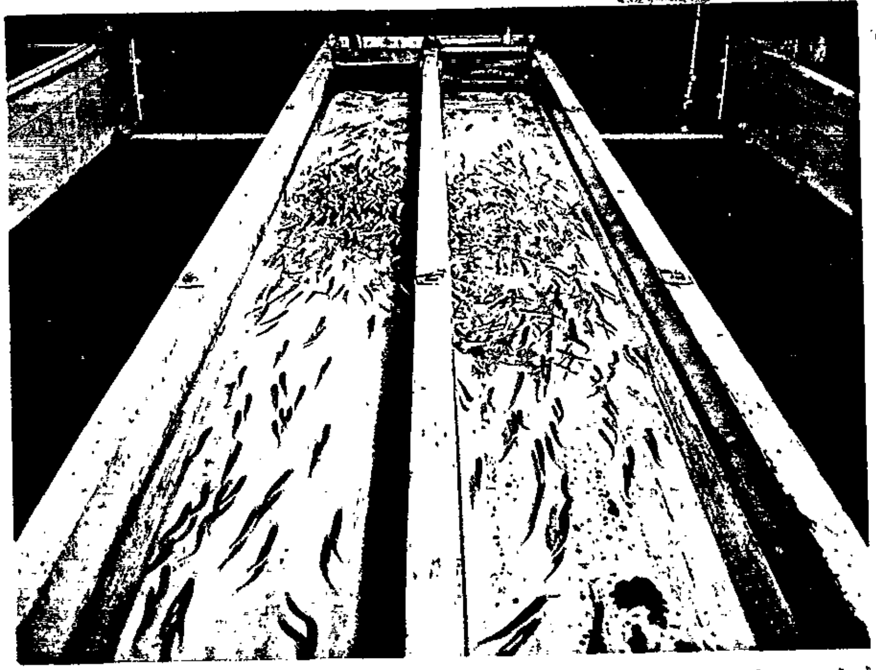
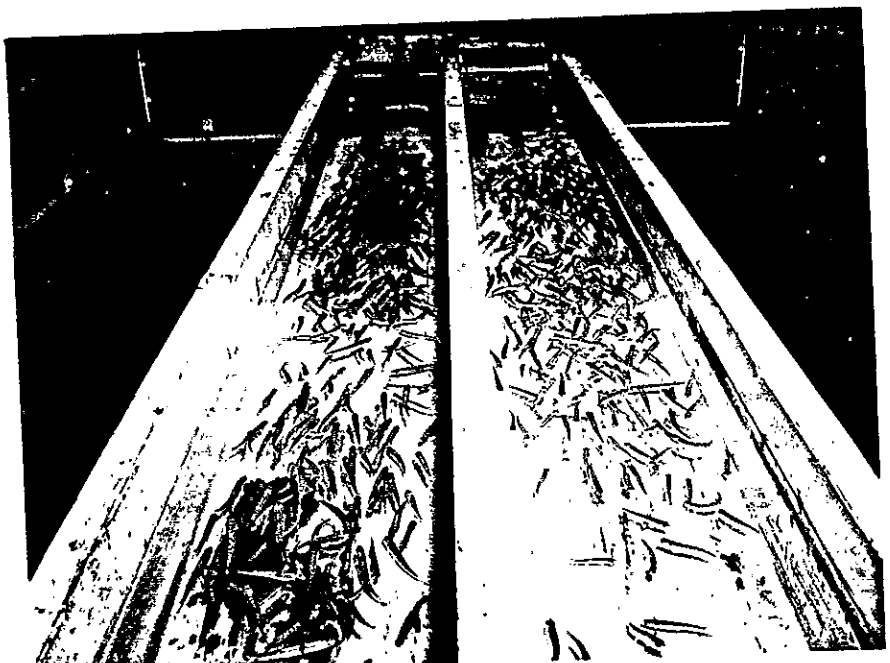


7-4157 C.3 8/31/46

PLATE XXII
Chinook Salmon Fingerlings in Troughs 15 and 16
1:1000 7-2-46



1-4151 C.3 7/31/46

PLATE XXIII
Chinook Salmon Fingerlings in Troughs 13 and 14
1:500 7-2-46

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PLATE XXIV
Chinook Salmon Fingerlings in Troughs 11 and 12
1:250 7-2-46

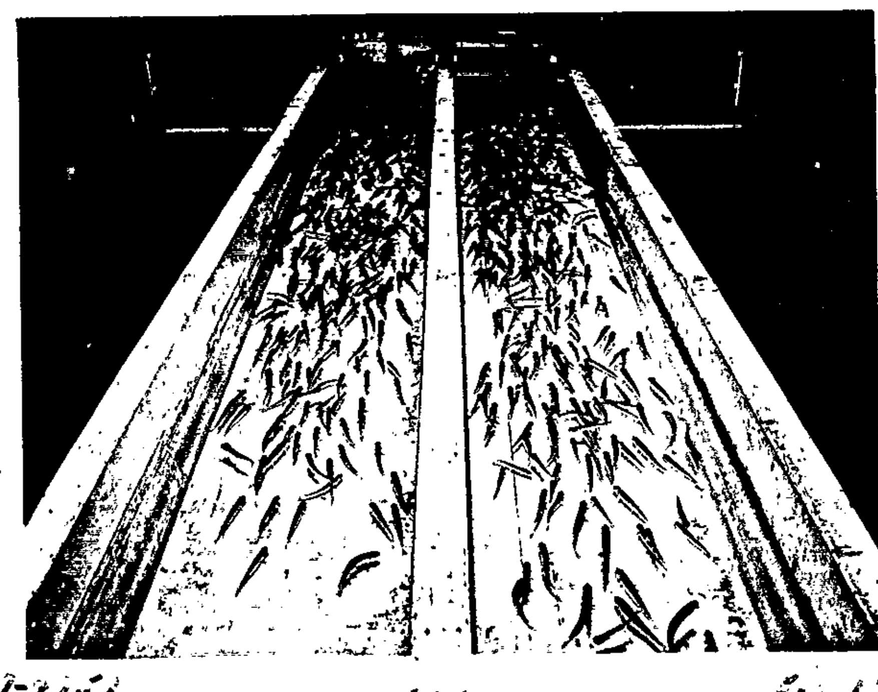


PLATE XXV
Chinook Salmon Fingerlings in Troughs 9 and 10
1:50 7-2-46

[redacted]

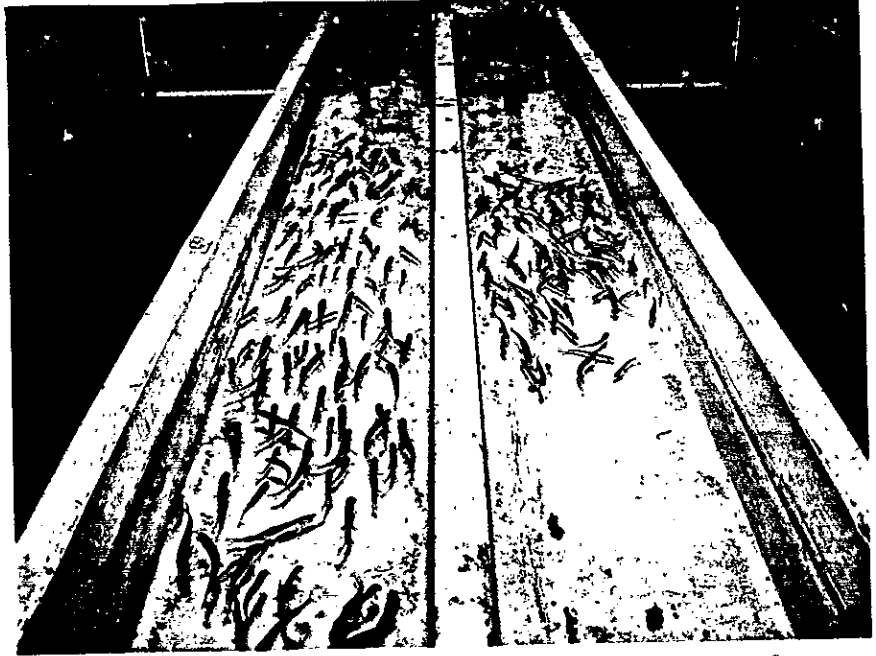


PLATE XXVI
Chinook Salmon Fingerlings in Troughs 7 and 8
1:10 7-2-46

PLATE XXVII
Chinook Salmon Fingerlings in Troughs 5 and 6
1:3 7-2-46 [redacted]

7 4759

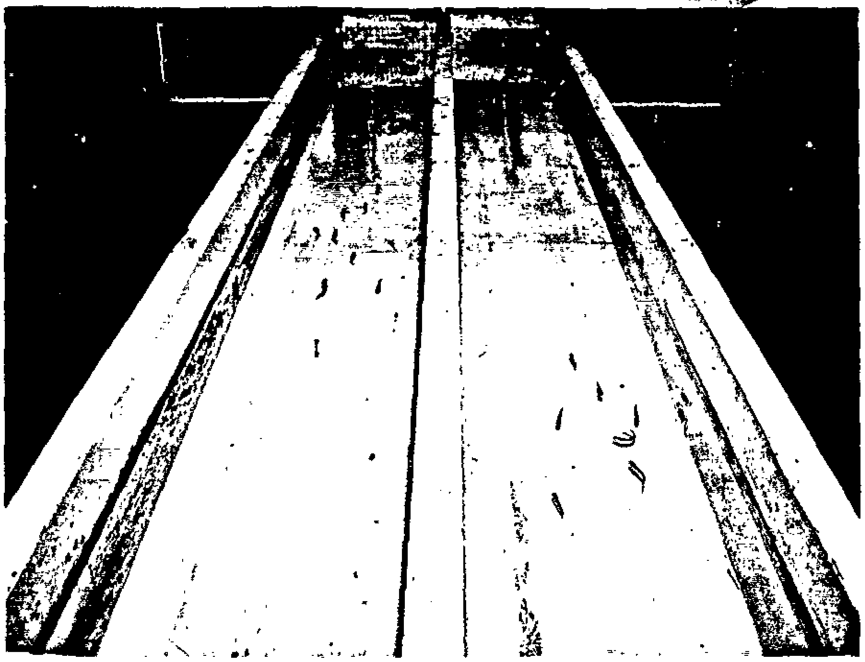


PLATE XXVIII
Chinook Salmon Fingerlings in Troughs 3 and 4
Refrigerated Effluent Water 7-2-46

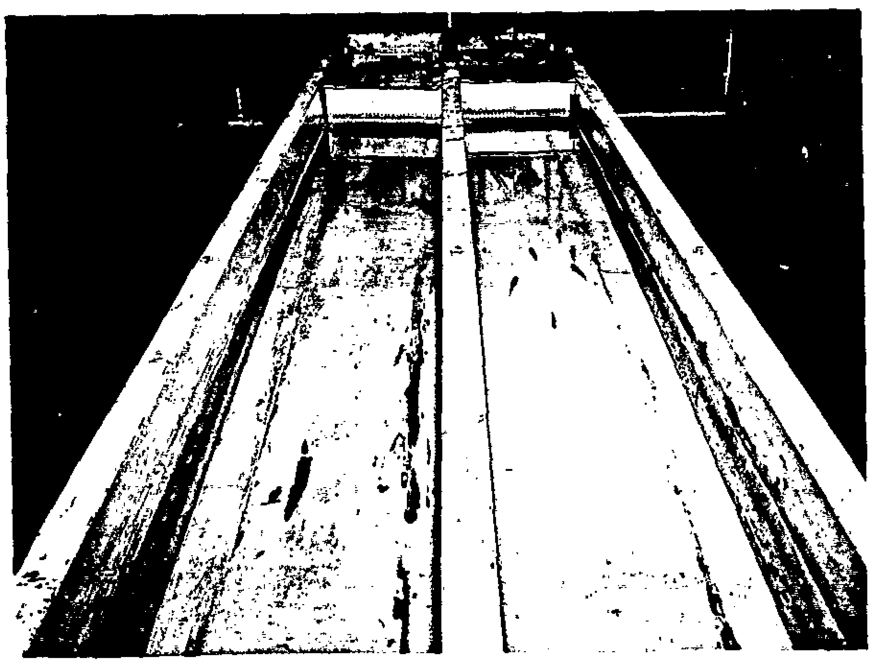


PLATE XXIX
Chinook Salmon Fingerlings in Troughs 1 and 2
Effluent Water 7-2-46

[redacted]

any embryo formation might be observed. The eggs examined were arbitrarily classified into the following six stages:

A. Those which were infertile or showed no evidence of embryo formation.

B. Those which were fertile but had developed only as far as blastoderm formation.

C. Those in which a definite embryo was formed but had survived only to the formation of the chorda or primitive streak.

D. Those in which development had advanced to the formation of somites, fin buds and optic vesicles but where the total length of the embryo was less than half the circumference of the egg.

E. Those in which the length of the well formed embryo exceeded half the circumference of the egg.

F. Those which died in hatching. This includes principally those eggs which are called "high-pressures" and which hatched abortively.

Appendix Table 18 shows the number of eggs which died in each tray or egg lot and the stage in which death occurred. Table VIII summarizes the data on Table 18 by pooling egg lots which were incubated in like water conditions and presents the results as percentages. Figure 8 is a graphic representation of Table VIII. As is frequently the case with salmon egg mortality data, there was considerable variation between the mortalities in trays incubated in like water conditions. The variations were sufficiently great so that a chi-square test did not show them to be homogenius, and precluded simple comparisons of the pooled means for the various water types. However, a sufficient number of trays were used in each dilution level to permit the use of more elaborate statistical tests. A t-test based on an array of lot mortality percentages was sensitive enough to show significant differences in the more diverse cases, and an extensive variance analysis provided a delicate test for borderline cases. In Table VIII the total mortalities which are significantly higher than those of the river water control group are underlined.

The consistant and orderly arrangement of the results as shown by Figure 8 is striking. In the undiluted and unrefrigerated effluent water virtually every egg remained undeveloped. A major part of this effect was, however, due solely to the warm temperature of the effluent water since in the undiluted effluent refrigerated to river water temperature about seventy per cent of the eggs hatched. The greater effect of temperature over other factors is also shown by the fact that the 1:50, 1:10 and 1:3 dilutions, in which the water temperatures were progressively higher than that of the river water, had mortalities which were in the same manner progressively greater than that of the undiluted but refrigerated effluent group. In the 1:250 and 1:500 dilutions the water temperatures were not appreciably greater than that of the straight river water but other adverse factors in the effluent caused mortalities significantly greater than in the control and these mortalities were in direct relation to the amount of effluent water present. The

 [redacted]

slight difference between the mortality in the 1:1000 dilution and that in the straight river water was not statistically significant. But the fact that one part effluent water in five hundred parts of river water measurably increased the mortality of these incubating chinook salmon eggs is of considerable interest.

The combination of high temperature and high effluent concentration existing at the 1:3 dilution level gave results very much like those of the straight effluent water; that is, virtually all of the eggs failed to develop, a few did succeed in forming a germinal disc but none lived beyond an early "eyed" stage. Only about fifty per cent of the eggs hatched at the 1:10 dilution level.

Since none of the eggs in the unrefrigerated effluent or in the 1:3 dilution hatched, the lots in these water conditions were re-established with a new series as mentioned in the preceding section (indicated by N. S. in Table VIII and Figure 8). The eggs in this new series had reached the eyed stage at the time they were placed in Troughs 1, 2, 5 and 6. A comparison of the subsequent mortalities in these new lots with the mortality of the control during a like period of development again showed a greater death for the eggs incubated in the effluent water but no significant difference in the 1:3 dilution. Further consideration of Table VIII and Figure 8 reveals that the greater part of the egg mortality occurs in Stage "A" and is, therefore, due either to infertility or a near complete lack of development. The direct relationship between mortality and concentration of effluent water just discussed for the total mortalities applies also to Stage "A" alone. Similarly, if each stage is considered independently of all others this same relationship is maintained in nearly every case; Stage "F" is an exception and the refrigerated effluent water group is an exception.

Abnormalities

Soon after hatching the young fry were carefully inspected and those which were deformed or otherwise appeared abnormal were removed. The percentage of abnormal fry found in each water type is shown in Table VIII below the egg mortality data. The 1:10 and 1:50 dilution levels were the only ones in which abnormality percentages were significantly higher than in the controls, the difference in the 1:50 group being questionable. Since the number of abnormal fry hatched in refrigerated area effluent water was practically the same as in river water, there is good evidence that for the types recognized at this time, increased percentages of abnormalities were the result of increased water temperatures rather than other inherent effects of the effluent water. A large part of the deformed fish occuring in the 1:10 dilution exhibited distorted vertebral columns.

Since none of the original eggs placed in straight effluent water or in the 1:3 dilution hatched, there obviously could be no abnormal fry in these lots. In the new series groups which replaced these lots, however, the number of abnormal fry was very low, which indicated that such deformities were the result of adverse factors operating during the early developmental stages of the eggs. The significantly higher percentage of abnormalities in the river water control group over that of the new series groups in Troughs 1, 2, 5 and 6 is probably the result of the extra handling received by the control group. The eggs in the river water were under experimental conditions

9 2 1 2 1 7 3 1 5 1 9

TABLE VIII

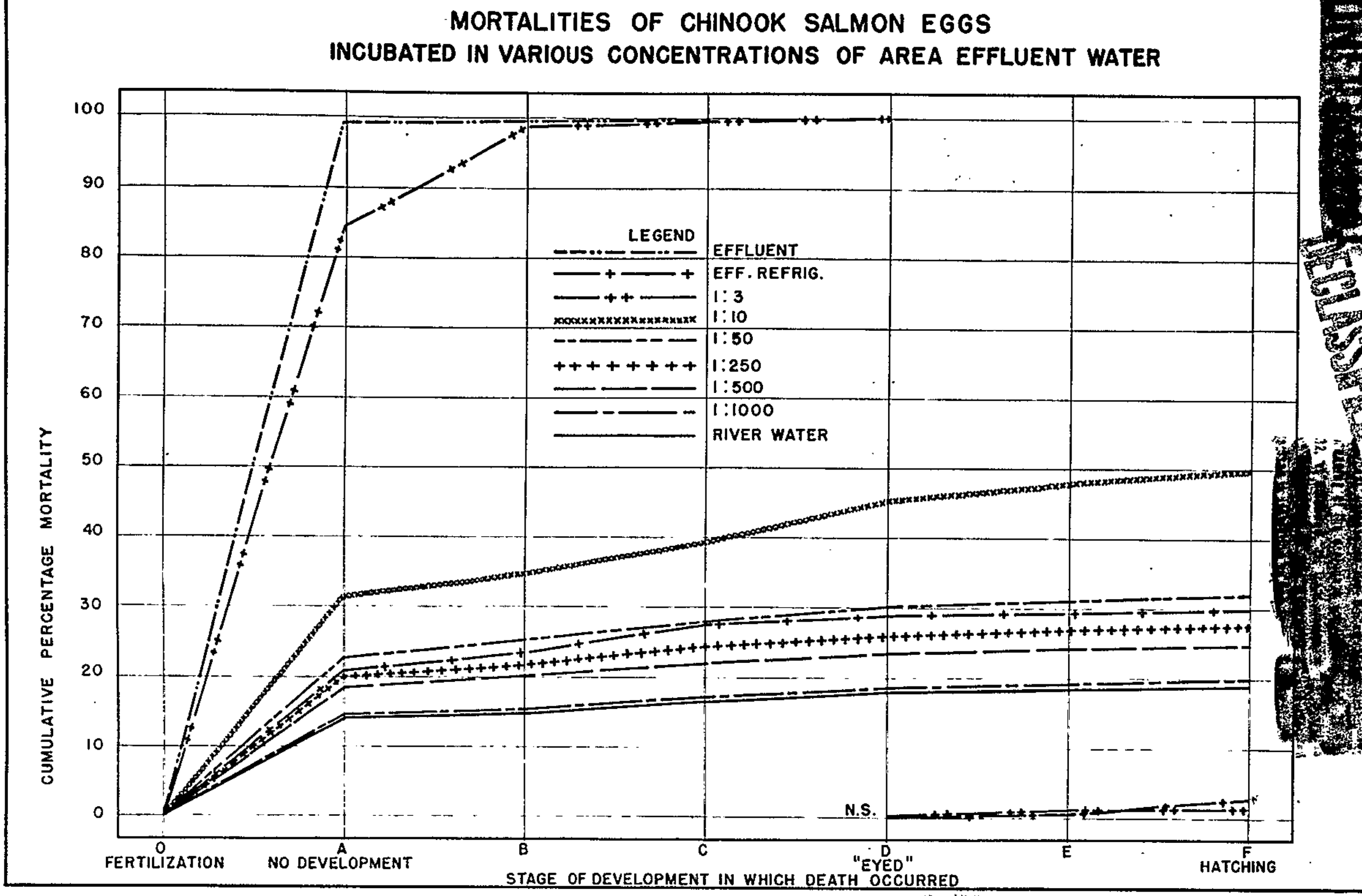
PERCENTAGE MORTALITIES AND ABNORMALITIES OF CHINOOK SALMON EGGS INCUBATED IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER

Type of Water	Effluent	Effluent N.S.	Refrigerated Effluent	1:3	1:3 N.S.	1:10	1:50	1:250	1:500	1:1000	River Water
Lot Nos.	1A, 1B 2A, 2B	1C, 1D 2C, 2D	3A, 3B 4A, 4B	5A, 5B 6A, 6B	5C, 5D 6C, 6D	7A, 7B 8A, 8B	9A, 9B 10A, 10B	11A, 11B 12A, 12B	13A, 13B 14A, 14B	15A, 15B 16A, 16B	17A & B, 18A & B 19A & B, 20A & B
Stage A	99.36	.03	20.80	84.31	.21	31.11	22.58	19.99	18.10	14.36	14.10
Stage B	.59	.00	2.62	14.46	0	3.49	2.73	1.62	1.94	.91	.74
Stage C	.05	.00	4.27	1.11	0	4.47	2.88	2.85	2.27	1.98	1.69
Stage D		.15	1.53	.12	.13	6.07	2.17	1.60	1.39	1.60	1.54
Stage E		1.28	.43	0	1.37	2.60	1.07	1.11	.90	.74	.74
Stage F		2.32	.53	0	.48	1.76	.73	.85	.59	.86	.43
Total	100	3.78	30.19	100	2.19	49.50	32.17	28.02	25.18	20.45	19.23
Abnormalities		.08	1.30		.08	4.73	2.31	1.21	1.76	1.42	1.39

Stage A - Not developed
Stage D - Eyed
Stage F - Hatching

9 2 1 2 7 3 0 5 2 1

FIGURE 8



during their early development, while those hatching in the effluent and 1:3 groups were not handled experimentally until after reaching the "eyed" stage.

Fry

The daily records of the numbers of fry dying in each trough have been condensed into weekly intervals and are given in appendix Table 19. The mortalities in lots subjected to like water conditions were sufficiently homogeneous to permit the pooling of the results into groups, and Table IX presents the combined mortalities together with their cumulative percentages. The data of Table IX are shown graphically in Figure 9, where a log scale has been used above the one per cent level in order to more clearly define the curves in the lower percentage levels.

Although the re-established or new series egg lots in the straight effluent water hatched quite successfully, the fry soon began to die in large numbers. There was a brief pause in mortality rate between the third and fourth week after hatching; then there was a second wave of mortality, which completely eliminated the lot by the ninth week. In Troughs 3 and 4 where the effluent water was refrigerated, the cooler temperature delayed development, and mortalities greater than those in the controls did not appear until between the third and fourth week after hatching; subsequently, the history of this group was much like that of the group in the unrefrigerated effluent water, but extended over a greater period of time. Following the first surge of mortality, which accounted for only about 3 per cent of the fry, there was a pause in mortality rate for about three weeks. A second and much larger wave of mortality then virtually wiped out the group.

The fry in the 1:3 dilution, which had also hatched from re-established egg lots, began to die in appreciable numbers at about the same time as those in the refrigerated effluent water. Here, however, there was no pause in the curve, and a high rate of mortality was maintained until the group was practically eliminated.

In the 1:10 dilution the rate of mortality in the developing eggs had been appreciably higher than in the weaker dilutions. This higher rate was maintained during the fry stage and resulted in the death of about 20 per cent of these fish. Again there was a brief period when the rate of mortality slackened; the pause occurred in this group between the second and fourth weeks.

The 1:50, 1:250, 1:500, and 1:1000 dilution levels did not significantly increase the mortality during the fry stage. It is interesting to note, however, that nearly all of these curves show a period of lower mortality rate between the fourth and eighth week, that is, during the month of January, 1945. Whether this is related to the deflections in the effluent, refrigerated effluent, and 1:10 dilution is not clear. Indeed, the reason for such deflections is not apparent. One might conjecture that the fry passed through a stage in which they were more resistant to adverse conditions or that different physiological factors in the fish were being effected at different times. The deflections occurred near, but somewhat preceded, the period of coldest water temperatures.

9 2 1 2 5 3 7 3 1 5 2 2

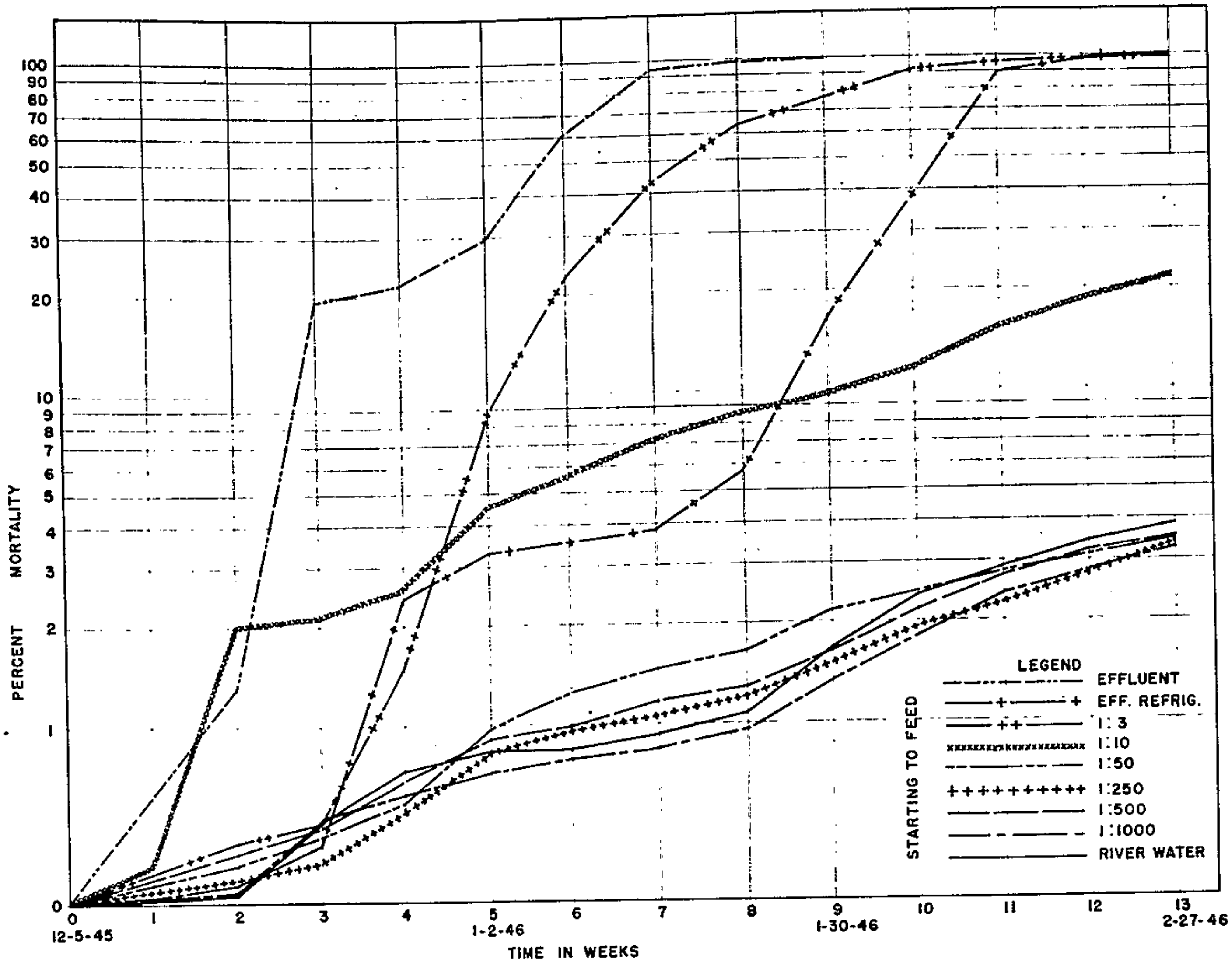
TABLE IX

MORTALITIES OF CHINOOK SALMON FRY REARED
IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER

Type of Water	Effluent		Refrigerated Effluent		1:3		1:10		1:50		1:250		1:500		1:1000		River Water	
Lot Nos.	1r & 2r		3 & 4		5r & 6r		7 & 8		9 & 10		11 & 12		13 & 14		15 & 16		17,18,19,20	
No. of Fish	3664		2817		3606		2137		2749		3009		3133		2773		6875	
Date	Mort	Cum %	Mort	Cum %	Mort	Cum %	Mort	Cum %	Mort	Cum %	Mort	Cum %	Mort	Cum %	Mort	Cum %	Mort	Cum %
---12/5/45			1	.03			5	.23										
12/6-12/12	48	1.31	2	.10	12	.33	38	2.01	6	.22	4	.13			2	.07	5	.07
12/13-12/19	657	19.24	6	.32	5	.47	2	2.11	4	.36	3	.23	13	.41	11	.47	27	.47
12/20-12/26	81	21.45	59	2.41	37	1.50	10	2.57	5	.55	8	.50	9	.70	4	.61	19	.74
12/27-1/2/46	291	29.39	25	3.30	263	8.79	43	4.59	12	.98	10	.83	7	.93	3	.72	7	.84
1/3-1/9	1140	60.51	6	3.51	499	22.63	22	5.61	7	1.24	1	.86	2	.99	2	.79		.84
1/10-1/16	1237	94.27	10	3.87	703	42.12	32	7.11	6	1.46	6	1.06	6	1.18	2	.86	6	.93
1/17-1/23	197	99.64	53	5.75	656	60.32	32	8.61	5	1.64	4	1.20	3	1.28	3	.97	9	1.06
1/24-1/30	13	100	310	16.75	586	76.57	22	9.64	15	2.18	9	1.50	11	1.63	10	1.33	42	1.67
1/31-2/6	All		623	38.87	550	91.82	43	11.65	7	2.44	13	1.93	17	2.17	13	1.80	49	2.39
2/7-2/13			1423	89.39	197	97.28	79	15.35	10	2.80	10	2.26	17	2.71	16	2.38	32	2.85
2/14-2/20	Dead		252	98.33	40	98.39	74	18.81	9	3.13	15	2.76	15	3.19	11	2.78	38	3.40
2/21-2/27			42	99.82	22	99.00	68	21.99	9	3.46	19	3.39	10	3.51	13	3.25	30	3.84

FIGURE 9

MORTALITIES OF CHINOOK SALMON FRY
INCUBATED IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER



[redacted] DECLASSIFIED [redacted] 3

7 4759

Fingerlings

The distinction between the fry and fingerling stages is rather arbitrary, but is here characterized by an active feeding response by the fish in most of the troughs. At this time it was also necessary and convenient to reduce the number of fish in each trough to approximately five hundred. As mentioned in a preceding action, new stocks were placed in Troughs 1, 2, 3, 4, 5 and 6 since practically all of the fry in these troughs had died.

The mortality data for the fingerlings was handled in precisely the same manner as that for the fry. Appendix Table 20 shows the weekly mortalities for the various troughs or lots. Again, the data within each water type were sufficiently homogeneous to justify pooling the results into the group means shown in Table X. The cumulative percentages of Table X have been plotted in Figure 10, which also utilizes a log scale above the one per cent mortality level.

Although the fingerlings in the effluent, refrigerated effluent, and 1:3 dilution had not previously been subjected to area effluent water, their mortalities immediately rose above that of the controls, and an extremely high rate of death continued in these groups until nearly all of the fish were dead. As had occurred with the fry, the fingerlings held in unrefrigerated effluent water were affected quickly, while in the refrigerated effluent and 1:3 dilution, the response was slower; the ultimate result, however, was much the same.

The death rate in the 1:10 dilution exceeded that in the straight effluent water during the first three weeks. This was because the fingerlings in the 1:10 dilutions were held over in Troughs 7 and 8 from the fry stages, and a high mortality rate was already present in these fish at the time the fingerlings data were started. At the time the experiment was terminated, over 60 per cent of the fingerlings in the 1:10 dilution had died; although this is about six times greater than that of the controls, it is of a lower order than the mortalities which occurred in Lots 1S through 6S.

In dilutions of 1:50 or greater, the effluent water did not significantly increase the mortality of the fingerling chinook salmon. Of the 6 to 10 per cent mortality suffered by the fingerlings in straight river water and the lower dilution levels, the greater part occurred during the last six weeks and was due to "gas bubble" disease.

Growth in Length and Weight

The growth in length and growth in weight followed identical tr nds, and so will be considered together. As in the previous experiments, length measurements were made every four weeks, and the fish were weighed in groups every two weeks. The length measurements taken at each sampling date are are shown in appendix Tables 21 to 27, and the average weights in appendix Table 28. In general, the sizes of the fish in lots reared under like water conditions are in good enough agreement to allow pooling of the data. Table XI shows the average lengths of the salmon in each water type on each sampling date; underlined values are significantly lower than those of the control group. Table XII shows the average weights after pooling similar data of appendix Table 28.

 [redacted]

TABLE X

MORTALITIES OF CHINOOK SALMON FINGERLINGS (SERIES 2)
REARED IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER

Type of Water	Effluent		Refrigerated Effluent		1:3		1:10		1:50		1:250		1:500		1:1000		River Water	
Lot Nos.	1S & 2S		3S & 4S		5S & 6S		7 & 8		9 & 10		11 & 12		13 & 14		15 & 16		17,18,19,20	
No. of Fish	981		972		969		953		988		994		989		993		1982	
Date	Mor_t	$Cum_{\%}$	Mor_t	$Cum_{\%}$	Mor_t	$Cum_{\%}$	Mor_t	$Cum_{\%}$	Mor_t	$Cum_{\%}$	Mor_t	$Cum_{\%}$	Mor_t	$Cum_{\%}$	Mor_t	$Cum_{\%}$	Mor_t	$Cum_{\%}$
2/28-3/6	6	.61	4	.41	5	.52	20	2.10	3	.30	1	.10	4	.40	2	.20	5	.25
3/7-3/13	8	1.42	3	.72	2	.72	24	4.62	3	.61	3	.40	1	.51	4	.60	1	.30
3/14-3/20	7	2.14	9	1.65	3	1.03	23	7.03	1	.71	4	.80	1	.61	2	.81	4	.50
3/21-3/27	128	15.19	6	2.26	5	1.55	17	8.81	1	.81	1	.91	1	.71	1	.91	1	.55
3/28-4/3	264	42.10	15	3.81	10	2.58	15	10.39	1	.91	2	1.11	0	.71	2	1.11	1	.61
4/4-4/10	152	57.59	30	6.89	26	5.26	11	11.54	1	1.01	0	1.11	1	.81	1	1.21	7	.96
4/11-4/17	49	62.59	46	11.63	44	9.80	14	13.01	2	1.21	1	1.21	1	.91	3	1.51	4	1.16
4/18-4/24	95	72.27	129	24.90	67	16.72	26	15.74	2	1.42	1	1.31	1	1.01	1	1.61	5	1.41
4/25-5/1	70	79.41	123	37.55	129	30.03	49	20.88	3	1.72	3	1.61	2	1.21	1	1.71	3	1.56
5/2-5/8	75	87.05	162	54.22	179	48.50	61	27.28	3	2.02	2	1.81	5	1.72	2	1.91	5	1.82
5/9-5/15	33	90.42	90	63.48	77	56.45	59	33.47	7	2.73	4	2.21	2	1.92	2	2.11	6	2.12
5/16-5/22	8	91.23	119	75.72	46	61.19	49	38.61	3	3.04	2	2.41	3	2.22	4	2.52	9	2.57
5/23-5/29	26	93.88	66	82.51	26	63.88	49	43.76	17	4.76	4	2.82	2	2.43	3	2.82	9	3.03
5/30-6/5	24	96.33	76	90.33	31	67.08	64	50.47	15	6.28	7	3.52	9	3.34	3	3.12	16	3.83
6/6-6/12	14	97.76	57	96.19	37	70.90	47	55.40	9	7.19	3	3.82	11	4.45	4	3.52	25	5.10
6/13-6/19	3	98.06	7	96.91	36	74.61	21	57.61	10	8.20	10	4.83	5	4.95	3	3.83	36	6.91
6/20-6/26	9	98.98	5	97.43	124	87.41	33	61.07	15	9.72	12	6.04	8	5.76	10	4.83	42	9.03
6/27-7/3	2	99.18	5	97.94	46	92.16	17	62.85	9	10.63	4	6.44	3	6.07	5	5.34	11	9.59

FIGURE 10

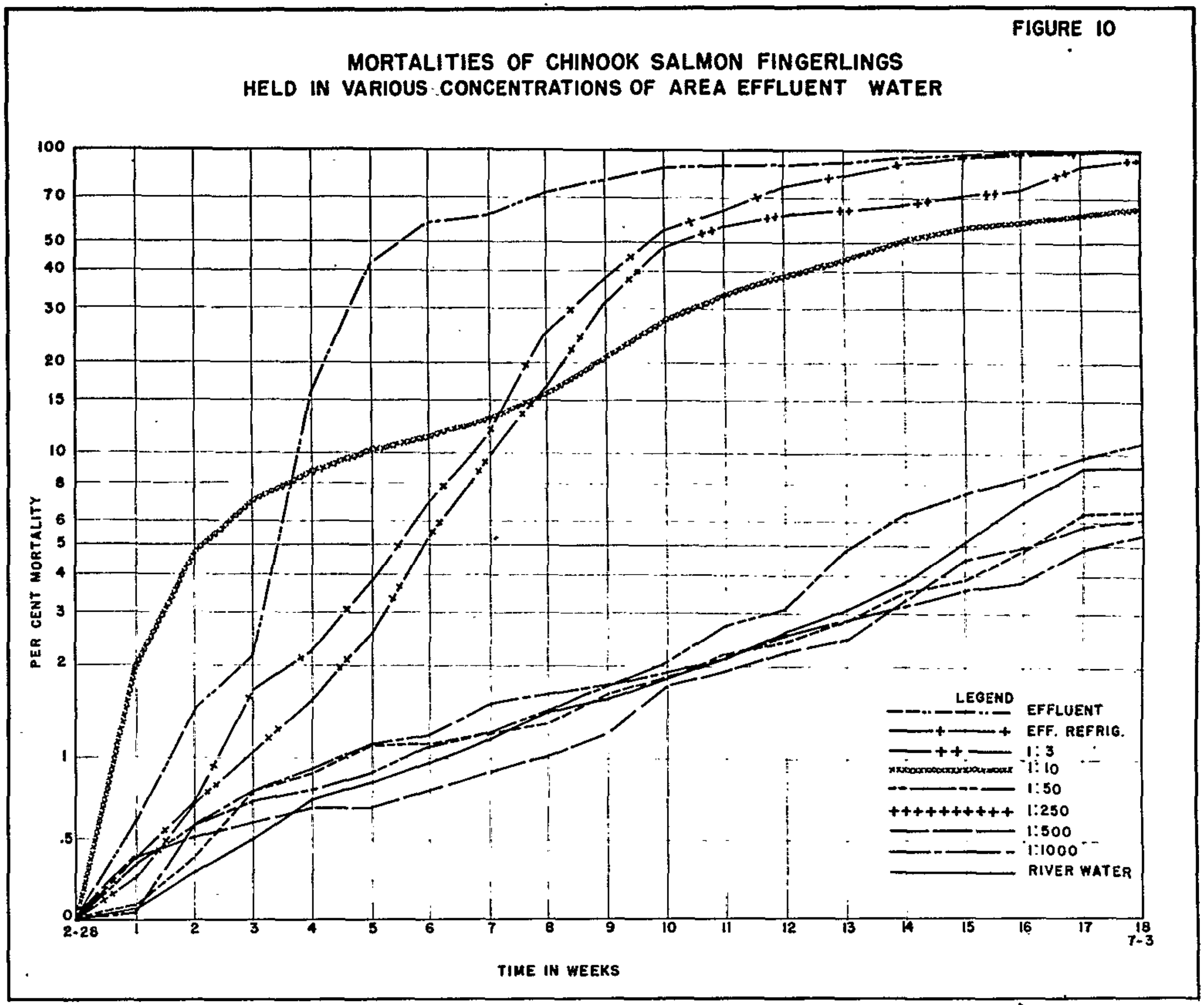

MORTALITIES OF CHINOOK SALMON FINGERLINGS
HELD IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER
PER CENT MORTALITY
100
70
50
40
30
20
15
10
8
6
5
4
3
2
1
.5
0
2-28
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
7-3
TIME IN WEEKS
LEGEND
EFFLUENT
EFF. REFRIG.
1:3
1:10
1:50
1:250
1:500
1:1000
RIVER WATER

TABLE XI

LENGTHS OF CHINOOK SALMON FINGERLINGS (SERIES 2) REARED IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER

Type of Water	Effluent	Refrigerated Effluent	Refrigerated Effluent	1:3	1:3	1:10	1:50	1:250	1:500	1:1000	River Water
Lot Nos.	1S & 2S	3 & 4	3S & 4S	5 & 6	5S & 6S	7 & 8	9 & 10	11 & 12	13 & 14	15 & 16	17,18,19,20
Jan. 30-31		30.3		31.0		34.6	33.9	33.5	33.6	33.4	33.5
Feb. 26	37.1	31.6	36.9	31.6	37.0	37.0	37.6	37.1	36.9	36.9	36.9
March 27	39.0		37.7		39.9	39.0	41.2	40.6	40.7	41.1	40.3
April 25	41.0		39.2		41.8	43.7	45.5	44.2	44.7	45.4	44.8
May 22	42.3		40.4		45.7	49.3	53.3	53.0	52.4	53.4	53.4
June 19	45.4		43.5		50.4	62.7	65.7	63.6	64.8	65.6	63.9
July 3	49.0		45.9		61.3	70.6	70.7	72.3	70.7	72.5	70.1

FIGURE 11

GROWTH IN LENGTH OF CHINOOK SALMON FINGERLINGS (SERIES 2)

HELD IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER

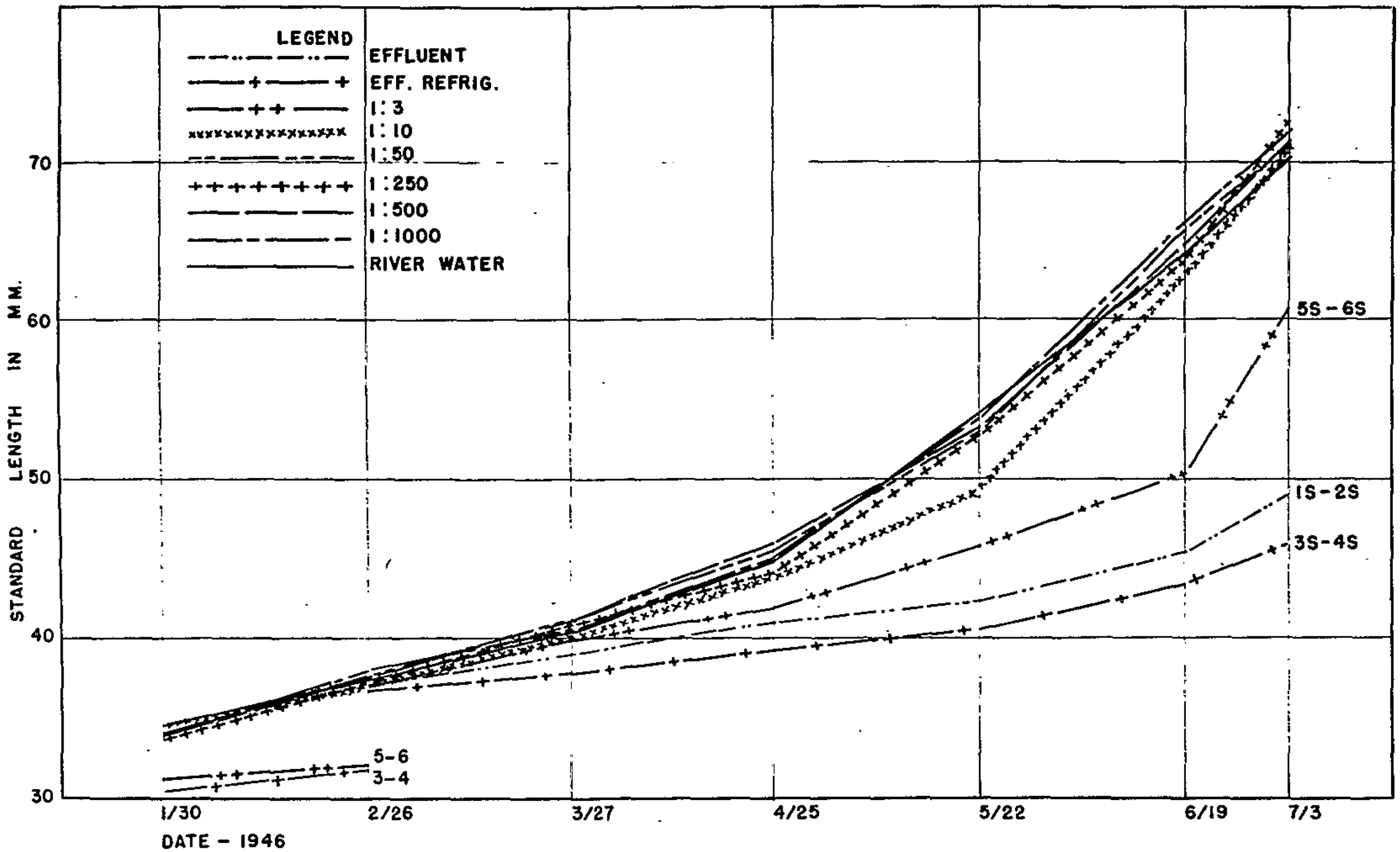


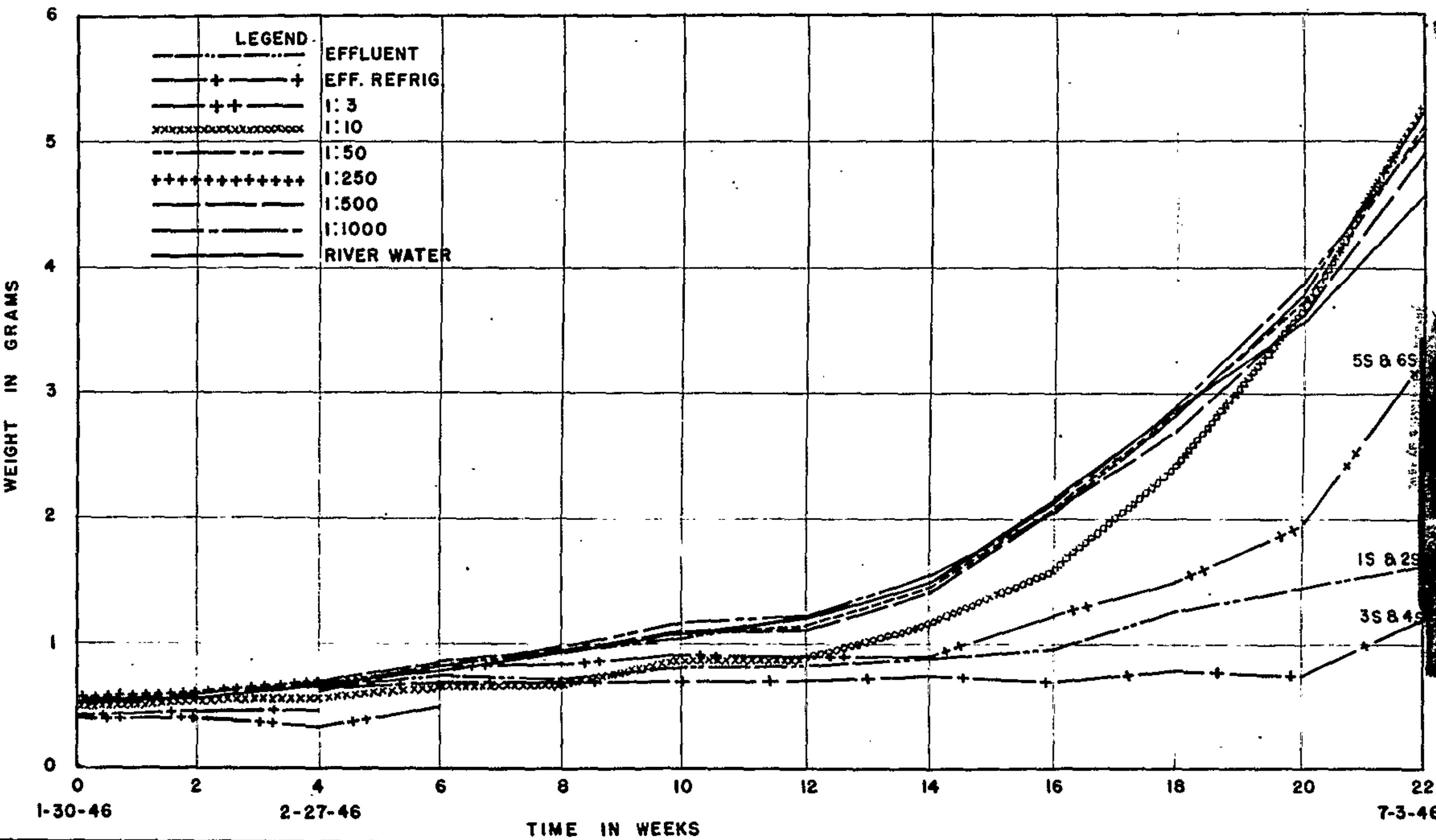
TABLE XII

AVERAGE WEIGHT IN GRAMS OF CHINOOK SALMON (SERIES 2) HELD IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER

Type of Water	Effluent	Refrig.Eff.	Refrig.Eff.	1:3	1:3	1:10	1:50	1:250	1:500	1:1000	River Water
Lot Nos.	1S & 2S	3 & 4	3S & 4S	5R & 6R	5S & 6S	7 & 8	9 & 10	11 & 12	13 & 14	15 & 16	17,18,19,20
1/30/46		.43		.40		.49	.52	.53	.53	.52	.50
2/13	.	.45		.41		.55	.60	.58	.60	.60	.57
2/27	.67	.44	.66	.33	.64	.57	.68	.68	.67	.68	.65
3/13	.76		.70	.50	.82	.63	.81	.80	.82	.82	.79
3/27	.73		.70		.85	.68	.98	.94	.95	.97	.95
4/10	.81		.71		.92	.87	1.17	1.09	1.10	1.13	1.07
4/25	.83		.74		.89	.97	1.23	1.15	1.12	1.21	1.22
5/8	.89		.70		.95	1.08	1.54	1.46	1.41	1.49	1.50
5/22	.97		.79		1.24	1.60	2.07	2.09	2.04	2.15	2.15
6/5	1.27		.77		1.50	2.41	2.84	2.85	2.71	2.90	2.87
6/19	1.45		1.19		1.95	3.65	3.80	3.75	3.64	3.85	3.59
7/3	1.62		1.20		3.25	5.29	5.26	5.12	4.92	5.03	4.58

FIGURE 12

GROWTH IN WEIGHT OF CHINOOK SALMON FINGERLINGS (SERIES 2)
HELD IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER



The nature of the weight data, which gave only average values without indicating the variation in size between individuals in each lot, make it impossible to test for significant differences between lots by ordinary methods. Further, rates of growth could not easily be compared statistically since they neither followed a straight line relationship nor curves of equations of the first degree; however, the significance of size differences between the various groups was adequately shown by the length data where each group was compared to the control by the "t-test".

Figures 11 and 12 depict the growth of the fish in length and weight, respectively. Size measurements were first made at the end of January, 1946, before the fry had completely absorbed their yolk sac. The improper utilization of the yolk by the fry in Lots 3, 4, 5r and 6r, held in refrigerated effluent and the 1:3 dilution, is evident in Figure 11. The lengths of these fry are significantly smaller than those of other lots, but because of their relatively larger amount of unabsorbed yolk, their weights were only slightly smaller. None of the fry in the unrefrigerated effluent water of Troughs 1 and 2 survived at this time, and those remaining in Lots 3, 4, 5r and 6r soon died without showing appreciable growth.

The fingerlings placed in Troughs 1 through 6 to replace the fry which had died immediately showed significantly slower rates of growth than those in the other troughs. The poorest growth occurred in the refrigerated effluent water where both low temperature and adverse conditions operated together. In the unrefrigerated effluent water, the fish grew only slightly faster although temperatures were favorable for rapid growth. At a similarly favorable temperature, but with the effluent diluted with three parts of river water, growth was somewhat better than in the undiluted effluent groups, but still markedly slower than in the controls. In this group, which includes Lots 5s and 6s, there is an apparent sharp increase in rate of growth during the last two weeks of the experiment. This is not actually the case, however, since only the largest and strongest individuals remained alive on July 3, 1946, to make up the final sample. Peculiarly, one fish in Trough 6 seemed more resistant to the adverse conditions and was able to take advantage of the more favorable water temperature, thus reaching a larger size than any other fish in the laboratory. (See Table 27)

In the 1:10 dilution, some of the fish were able to overcome much of the adverse effect of the effluent water and make rapid growth in the warmer water. Other individuals were seriously affected at this dilution level, grew scarcely at all, and were subject to disease. This resulted in a wide range of sizes of fish in Troughs 7 and 8, which was evident even during the late fry stage, and became greater as the experiment progressed. Although the average size of these fish was appreciably lower than that of the controls during March, April, and May, the differences were only of questionably significance statistically due to the great variation of sizes within the group. An apparent increase in growth rate during the last six weeks of the experiment in this group held in the 1:10 dilution makes their final size equal to, or a little larger than, that of the controls. Again this apparent increase is not real, but results from the deaths of smaller fish with the survival of larger ones.

In dilutions of 1:50 or greater, the effluent water did not retard the growth of the fingerling chinook salmon, Actually, on July, 3, the

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weight of the control fish was noticeably less than that of fish in weak dilutions of the effluent water, and effect which might be caused by slight temperature differences in proportion to the amount of effluent added.

Discussion

The difficulties in controlling experiment conditions which were experienced in the steelhead trout and chinook fingerling pilot studies fortunately did not enter this second series of chinook studies. Minor disease conditions attributable to a lowered resistance among the young fingerlings in the 1:10 dilution level were soon controlled, but some losses were sustained in river water and in the weaker dilution levels late in the experiment, due to "gas bubble" disease. In general, however, extraneous factors did not greatly influence this experiment, and the results obtained can be attributed to the controlled experimental conditions with reasonable certainty.

No change in experimental design was thought necessary during these studies; however, complete or near complete mortality of some of the groups necessitated restocking Troughs 1, 2, 5 and 6 with eyed eggs and Troughs 1, 2, 3, 4, 5 and 6 with fingerlings.

From the sections above, it is evident that the younger developmental stages of chinook salmon are somewhat more susceptible to the adverse factors in the area effluent water than are the older fingerlings; nevertheless, in all stages studied, undiluted effluent water and the dilution of one part effluent to three parts river water not only resulted in very poor growth and development, but were soon lethal.

At a dilution of one part effluent to ten parts river water, mortality was greatly increased in every stage. There were more abnormalities, and many of the surviving fish were undersized, weak, emaciated, and susceptible to disease. Some individual fish, however, were able to tolerate this concentration and make rapid growth.

When diluted with fifty or more parts of river water, the area effluent did not appear to adversely affect either the growth or the mortality of the fry or fingerling chinook salmon.

Early developmental stages of the eggs were, however, more sensitive, and a measurable increase in mortality was present in dilutions as low as one part area effluent water in five hundred parts of river water.

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OF__________COPIES, SERIES____________

9 2 1 2 2 7 3 0 5 3 4

A P P E N D I X

T A B L E S

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DECLASSIFIED

TABLE 1 A sample of the form used during the later experiments as a guide in adjusting Water Flows. [redacted]

146 BUILDING WATER FLOWS

Date 6-13-46

Shift 8-4

Time 10:30 - 11:00 AM

Checked by Schroeder

Supervisor Foster

Trough No.	Area Effluent Water			River Water		
	Should Flow	Was Flowing	Adjusted to	Should Flow	Was Flowing	Adjusted to
1	1900 cc/10 sec	1900		None		
2	1900 "	1900		None		
3	1900 "	1900		None		
4	1900 "	1900		None		
5	2400 cc/30 sec	2350	2400	2400 cc/10 sec	2150	2400
6	2400 cc/30 sec	2400		2400 cc/10 sec	2400	
7	286 cc/10 sec	285		2850 "	3000	2850
8	286 cc/10 sec	285		2850 "	2800	2850
9	62 "	62		3100 "	3100	
10	62 "	63	62	3100 "	3100	
11	75.5 cc/min	77	75	3150 "	3150	
12	75.5 "	61	75	3150 "	3150	
13	38 "	38		3150 "	3150	
14	38 "	38		3150 "	3150	
15	19 "	19		3150 "	3200	3150
16	19 "	19		3150 "	3150	
17	None			3150 "	3150	
18	None			3150 "	3150	
19	None			1900 "	1900	
20	None			1900 "	1900	

CONFIDENTIAL

TABLE 2 MORTALITIES OF CHINOOK SALMON FINGERLINGS HELD IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER

Preliminary Results

Lot No.	2A	1B	2B	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Water Type	Warm Eff.	Warm Eff.	Warm Eff.	River Water	River Water	1:500	1:500	1:50	1:50	1:100	1:100	1:250	1:250	1:500	1:500	1:1000	1:1000	River Water			
No. Fish	50	94	56	50	50	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	90
Mortality - 7/25-31	44	Started Aug.1	Aug.1	2	2	11	6	6	6	5	13	14	10	5	1	4	5	12	17	12	9
8/1-7		22	21	6	4	12	19	8	10	19	15	23	10	5	9	21	17	4	7	8	18
8/8-14		20	27	8	8	21	24	12	8	9	6	10	15	15	11	44	22	8	32	18	14
8/15-21		25	6	5	6	8	2	10	6	3	8	5	1	12	19	7	18	5	10	20	12
8/22-27		20	1	1	3	2	4	5	11	0	5	6	6	5	5	6	2	2	2	5	5
Total	44	87	55	22	23	54	55	41	41	36	47	58	42	42	45	82	64	31	68	63	58
%	88	92.6	98.2	44.0	46.0	54.0	55.0	41.0	41.0	36.0	47.0	58.0	42.0	42.0	45.0	82.0	64.0	31.0	68.0	70.0	64.4

9212 733537

TABLE 3

MORTALITIES OF CHINOOK SALMON FINGERLINGS HELD IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER

Results after regrouping of Lots on August 27, 1945

Lot No.	1C	2C	3C	4C	5C	6C	7C	8C	9C	10C	11C	12C	13C	14C	15C	16C	17C	18C	19C	20C
Water Type	Precooled Effluent		Refrigerated Effluent		1:500 Refrigerated		1:50		1:100		1:250		1:500		1:1000		Straight River Water			
No. Fish	44	42	23	44	44	41	46	43	44	46	44	45	43	44	43	44	44	43	44	43
Mortality 8/28-9/3	44	42	8	2	5	8	4	4	3	4	3	3	6	2	11	1	1	2	3	3
9/4-10			11	21	2	4	-	3	1	5	2	8	7	1	5	-	1	2	1	5
9/11-17				15	2	4	1	3	5	7	8	5	1	-	5	1	2	1	3	1
9/18-26			1	1	2	5	-	3	2	3	-	3	1	1	4	7	-	4		
Total	44	42	20	39	11	21	5	13	11	19	13	19	15	4	25	9	4	9	7	9
%	100	100	87.0	88.6	25.0	51.2	10.9	30.2	25.0	41.3	29.5	42.2	34.9	9.1	58.1	20.4	9.1	20.9	15.9	20.9

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TABLE 4

AVERAGE WEIGHTS IN GRAMS OF CHINOOK SALMON FINGERLINGS HELD IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER

Preliminary Weights

Type of Water	River Water				1:500		1:50		1:100		1:250		1:500		1:1000		River Water			
Lot No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
No. of Fish at Start	50	50	50	50	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Avg. Wt. 7-24-45	10.36	9.68	9.90	10.36	9.84	8.73	9.45	9.25	9.55	9.20	7.83	9.55	8.05	9.20	8.75	9.10	9.75	10.25	8.51	9.00
8-27-45			13.74	13.27	14.15	13.98	13.61	12.76	14.27	12.27	12.00	14.55	10.94	13.54	13.20	14.94	12.91	14.55	12.21	13.78

TABLE 5

Weights After Regrouping of Lots on August 27, 1945

Type of Water	Warm Eff.		Refrig. Eff.		1:500 Refrig. Eff.		1:50		1:100		1:250		1:500		1:1000		River Water			
Lot No.	1C	2C	3C	4C	5C	6C	7C	8C	9C	10C	11C	12C	13C	14C	15C	16C	17C	18C	19C	20C
No. of Fish at Start	44	42	23	44	44	41	46	43	44	46	44	45	43	44	43	44	44	43	44	43
Avg. Wt. 8-28-45	13.14	12.62	10.39	12.59	13.98	13.85	13.15	13.09	13.64	12.56	12.45	14.22	10.77	13.45	12.56	13.82	13.44	14.56	12.73	16.60
9-10-45			12.83	13.33	15.54	14.54	14.77	15.33	15.45	13.34	14.00	16.20	12.39	15.10	14.81	14.84	15.00	16.05	14.67	15.06
9-24-45			16.67	14.50	17.12	15.00	16.80	17.67	16.09	15.20	15.35	15.77	13.29	17.12	17.28	16.13	17.63	18.14	16.92	16.47

[redacted] DECLASSIFIED [redacted]

TABLE 6

Length Frequencies of Chinook Salmon Fingerlings
August 29 & 30, 1945

Lot Numbers

Length in M.M.	1C	2C	3C	4C	5C	6C	7C	8C	9C	10C	11C	12C	13C	14C	15C	16C	17C	18C	19C	20C
60		1						1						1						
65		1	2					1						1						
70		1			1		2			1	2			3		1				
75			1			1				1			1		1					1
80	1		2			2	2			2		1	6	1		1	3		1	
85		4		1	3	3	1	4	5	2	2	2	3	1	3	2	1	2	3	2
90	7	4	4	5	4	2	1		3	8	7	2	7	1	6	3	6	2	5	4
95	9	9	5	9	4	5	8	7	3	7	10	1	10	5	10	5	7	6	11	5
100	11	9	4	15	8	6	15	9	7	13	9	14	8	7	8	8	9	9	6	12
105	6	8	2	11	13	8	8	14	12	6	8	15	2	14	5	8	6	14	17	13
110	9	4	1	3	8	8	4	4	7	5	3	4	4	7	6	9	8	7	1	4
115			1		3	3	2	1	3		1	3		1	1	4	3	3		
120							1		2	1				1		2	1			1
125								1				1								
Total	43	41	22	44	44	38	44	42	42	46	42	43	41	43	40	43	44	43	44	42

 [redacted]

[redacted] DECLASSIFIED [redacted]

TABLE 7

Length Frequencies of Chinook Salmon Fingerlings
Sept. 24-25, 1945

Length M. M.	Lot Nos.																			
	1C	2C	3C	4C	5C	6C	7C	8C	9C	10C	11C	12C	13C	14C	15C	16C	17C	18C	19C	20C
60														1						
65								1			1									
70														1		1				
75							1						1	2						1
80						3	1			1			1			1	1			
85						2	1		3	2	3	1	5	2		1	2		1	
90			1		2		1	1	3		1	1	2	1	2		2		3	1
95					2	3	2	2	2	5	3	3	5	1	2	5	5	5	1	1
100	No Fish	No Fish		2	2	3	6	4	3	5	6	5	4	2	2	3	5	2	3	9
105					8	2	10	6	5	6	6	7	4	5	3	8	3	6	10	10
110			1		12	3	9	9	8	1	4	5	5	14	4	3	7	10	12	6
115			1		7	7	5	6	5	5	5	2	2	5	2	12	5	7	6	5
120						3	2		3		1	2		5	2	2	8	3		
125							1	1		1	1		1	1	1	1	1	1		
130							1										1	1		1
Total			3	2	33	26	40	30	32	26	31	26	30	40	18	37	40	35	36	34

[redacted]

TABLE 8

MORTALITIES OF STEELHEAD TROUT FINGERLINGS HELD IN THE PRELIMINARY CONCENTRATIONS OF AREA EFFLUENT WATER

Type of Water	Effluent		Refrigerated Effluent		1:500 Refrig.Eff.		1:50		1:100		1:250		1:500		1:1000		River Water			
Lot Nos.	1	2X	3X	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
No. of Fish	135	117	91	123	116	108	103	107	120	116	111	125	141	120	125	147	114	81	117	119
8-27 to 9-2	30	27	1	2	0	0	0	0	0	3	6	2	2	1	5	0	0	0	0	0
9-3 to 9-9	11	13	1	1	0	1	0	0	1	1	0	13	8	3	2	0	0	0	0	0
9-10 to 9-16	6	40	0	1	0	1	0	0	2	1	0	2	5	0	0	0	0	0	0	2
9-17 to 9-23	28	18	0	0	1	0	0	1	1	0	1	2	3	0	0	0	0	0	0	0
9-24 to 9-30	13	3	1	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0
10-1 to 10-7	2	1	0	1	2	0	1	0	0	1	0	0	0	0	0	1	1	0	0	0
10-8 to 10-11	2	3	1	1	1	0	0	2	0	0	0	0	0	0	0	0	0	0	1	1
Total	92	105	4	6	4	2	1	3	4	6	7	19	18	4	7	8	1	0	1	3

TABLE 9 MORTALITIES OF STEELHEAD TROUT FINGERLINGS HELD IN THE FINAL CONCENTRATIONS OF AREA EFFLUENT WATER

Type of Water	Effluent		Refrigerated Effluent		1:3		1:10		1:50		1:250		1:500		1:1000		River Water			
Lot Nos.	1A	2A	3	4	5A	6A	7A	8A	9A	10A	11	12	13	14	15	16	17	18	19	20
No. of Fish	48	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
10-12 to 10-18	30	50	48	50	23	28														
10-19 to 10-25	1				9	2				1										
10-26 to 11-1	2																1			
11-2 to 11-8	3																1			
11-9 to 11-15						1											1			
11-16 to 11-22	1				1												2			
11-23 to 11-29																				
11-30 to 12-6																	1			
12-7 to 12-13																				
12-14 to 12-20																				
12-21 to 12-27					1															
12-28 to 12-31													1							
Total	37	50	48	50	34	31				1			1				6			

TABLE 10

STEELHEAD TROUT LENGTH FREQUENCIES
AUGUST 15 - 16, 1945

Type of Water	Effluent		Refrigerated Effluent		1:500 Refrig.Eff.		1:50		1:100		1:250		1:500		1:1000		River Water			
Lot Nos.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Lengths in mm 35																				
40	2		1	1						1	1	1				2				
45			4	5				2	1	1		2	1	1	1	1				1
50	3	5	9	13	5	2	2	7	4	7	1	2	2	4	7	6	1	9	3	4
55	13	16	14	13	14	8	15	9	11	9	9	5	6	9	11	7	15	11	13	15
60	23	22	13	15	18	13	14	16	10	17	16	18	9	17	14	14	19	13	14	17
65	6	6	7	2	7	20	12	12	17	10	11	10	18	10	14	15	12	13	17	9
70	3			1	5	5	6	2	5	4	9	10	10	6	2	2	3	2	1	2
75		1	2			2		1	1	1	2	1	3	2	1	3		2	2	2
80					1		1	1				1	1	1						
85									1		1									
90																				

TABLE 11

STEELHEAD TROUT LENGTH FREQUENCIES
SEPTEMBER 10 - 13, 1945

Type of Water	Effluent		Refrigerated Effluent		1:500 Refrig.Eff.		1:50		1:100		1:250		1:500		1:1000		River Water			
Lot Nos.	1	2X	3X	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Lengths in mm 35				1																
40																				
45	3	2	2											1						
50	2	8	3	3							2			2		1			1	
55	12	12	3	8	2			3	1	1	2	1	1	3	5	4	1		1	2
60	21	22	16	11	7	6	4	3	6		5	2	5	4	6	6	6	4	4	6
65	9	3	13	13	11	9	14	10	11	5	4	11	8	7	6	6	9	10	10	12
70	3	2	8	11	9	13	14	13	11	16	11	11	15	10	12	14	15	8	12	17
75			2	3	7	10	12	4	10	8	12	12	11	14	11	7	12	10	9	9
80			2		9	4	3	8	5	14	7	5	2	2	8	9	4	7	6	5
85		1	1		2	8	2	6	6	2	5	5	4	4	2	3	1	7	5	2
90					2		1	1	1	2	2	1	2	2			2	3	2	2
95								1		1		1		1				1		
100					1					1		1	1							
105													1							

TABLE 12

STEELHEAD TROUT LENGTH FREQUENCIES
OCTOBER 9 - 10, 1945

Type of Water	Effluent		Refrigerated Effluent		1:500 Refrig.Eff.		1:50		1:100		1:250		1:500		1:1000		River Water			
Lot Nos.	1	2X	3X	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Lengths in mm 50	1	1																		
55	3	1		1																
60	10	1	2	4				1			1			2	1				1	
65	16	3	5	10		1		2		1	2	2	1		2	2	4	1		1
70	2	3	7	7	5	3	7	5	2	2	3	1	3	3	6	2	5	5	5	2
75	3	1	8	8	6	1	2	3	8	6	3	5	5	4	5	7	4	4	10	9
80	3		13	11	9	6	6	4	9	5	7	12	6	2	10	9	4	5	7	10
85			6	5	10	4	10	7	8	9	7	4	11	8	8	8	12	8	7	10
90			7	3	5	10	12	11	8	11	11	10	7	13	9	9	12	7	3	9
95			2		5	6	5	5	6	5	5	8	4	10	7	6	4	8	7	7
100				1	4	9	4	8	6	6	4	5	8	3	1	4	3	6	6	
105					3	7	2	2	2	2	4	3	2	2		2	1	4	3	1
110					1	2	1		1	3	3			1	1	1		1		
115					2	1	1	1					2				1		1	1
120								1						1						
125													1	2				1		

TABLE 13

STEELHEAD TROUT LENGTH FREQUENCIES
NOVEMBER 6, 1945

Type of Water	Effluent		Refrigerated Effluent		1:3		1:10		1:50		1:250		1:500		1:1000		River Water			
Lot Nos.	1A	2A	3B	4	5A	6A	7A	8A	9A	10A	11	12	13	14	15	16	17	18	19	20
Length in mm 55																				
60	2		1																	
65	3													1			1			
70	2				1	3				1				1	2				1	1
75	2		3		3	1		1	1	1	2					1		4		2
80	1				2		1	1	2	2	1	2	3	3	4	1	5		6	1
85			1		2		4	3	2	3	1	1	6	1	2	3	2	6	4	5
90			1		1	1	7	1	2	2	4	5	3	3	8	7	2	3	3	5
95			4		2	1	6	8	5	1	4	4	3	1	5	5	5	6	9	7
100			1		3	3	3	3	5	5	8	10	6	6	4	9	9	6	5	8
105			1		1		10	6	10	9	7	6	7	9	9	4	8	4	5	8
110			1			2	4	6	6	7	6	4	6	12	7	5	10	1	4	4
115							5	8	7	6	6	8	4	5	3	2	1	7	6	3
120					2	2	4	5	3	4	2	5	6	1	3	5	1	6	2	3
125						3	2	3	3	2	6	2	3	1		4	2	5	1	2
130					2	1	3	1	2	2	1	1	1	3	1	3	1		1	
135						1	1	2	1	2		1	1	1				1	2	
140						1		1			1			1						1
145																	1			
150										1	1		1	1				1		

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TABLE 14 STEELHEAD TROUT LENGTH FREQUENCIES
DECEMBER 4 - 5, 1945

Type of Water	Effluent		Refrigerated Effluent		1:3		1:10		1:50		1:250		1:500		1:1000		River Water			
Lot Nos.	1A	2A	3B	4	5A	6A	7A	8A	9A	10A	11	12	13	14	15	16	17	18	19	20
Length in mm 60																				
65	1		1														1			
70	1													2						
75	2		2			2													1	1
80			1						1						2			2		1
85	1		1		2	1				4	2					2	1		2	
90	2				2			3	1			2	2	2	2		1	1	1	1
95	1		1		2		4			1		2	3	2	4	2	5	4	7	4
100	1				2	1	5	2	3	1	3		3	1	2	4	3	5	2	4
105			3			1	5	2	1	2	4	3	5	1	5	3	1	2	8	5
110			3			2	2	5	3	2	3	4	2	3	3	5	3	5	3	4
115			1		2		5	5	2	4	4	6	6	4	8	7	4	5	6	6
120			1		2	2	3	6	10	5	8	6	4	9	8	8	8	5	1	9
125					1		6	1	9	10	6	10	5	7	7	3	6	4	4	4
130					1	2	6	5	8	5	4	4	6	5		2	3	1	7	1
135							4	7	6	5	3	3	6	6	3	2	4	7	3	1
140						1	2	4	1	3	4	4	2	2	3	7	1	5	1	3
145					2	1	2	4	2		7	3	2	1		1	2	1	1	1
150					1	2	2	2		2	1	1	1	1		1		2	1	
155					1	2	1	1	1	1		1	2	2		1				
160							1		1	1						1				
165						1	1			1	1		1							
170								1		1				1				1		1
175																	1			

TABLE 15

STEELHEAD TROUT LENGTH FREQUENCIES
JANUARY 1 - 5, 1946

Type of Water	Effluent		Refrigerated Effluent		1:3		1:10		1:50		1:250		1:500		1:1000		River Water			
Lot Nos.	1A	2A	3B	4	5A	6A	7A	8A	9A	10A	11	12	13	14	15	16	17	18	19	20
Length in mm 70	1																			
75			2											1						1
80	1					1												2		1
85	1		2		1	1				1	1				1				1	
90	1				2				1	2				2	2	1		1	1	
95			2		1		2	1	1	1	1	2	4			1	1	1	2	1
100					1		2	2		1	1		1	2	4	1	2	1	2	2
105	1				1	3	3	1	2	1		2	3	3	2	3	5	2	5	4
110	1		2		1	1	4	1	4	2	4	2	1		3	3	2	4	4	3
115	2		2				2	1	2		4	1	4	2	5	6	2	4	4	6
120			1			2	3	6		4	3	6	4	2	4	4	3	3	7	4
125			1				3	3	5	4	3	5	5	2	7	10	4	4	3	9
130			2		2		4	6	7	5	8	7	6	11	7	4	6	5	3	5
135					1	3	4	2	8	7	4	5	3	6	4	2	7	2	4	2
140					2		2	3	6	6	7	7	5	7	3	2	3	3	4	3
145					1		6	7	7	4	2	5	2	4	1	2	2	6	3	1
150							2	2	2	2	3	4	3	2	2	4	3	5		2
155						1	4	7	1		3	1	4	1	2	4	1	1	2	1
160						1	4	3		1	4		2	1				2	1	
165					3		1		1	3	1	2	1	2		1		1	2	
170						2		2	1	1						1	1			
175						2	1	1			1		1							1
180					1	1		1						1			1	1		
185							2			1										

TABLE [illegible]

STEELHEAD TROUT AVERAGE WEIGHT IN GRAMS
PRELIMINARY CONDITION

Type of water	Effluent		Refrigerated Effluent		1:500 Refrig.Eff.		1:50		1:100		1:250		1:500		1:1000		River Water			
Lot Nos.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
July 3[illegible]					3.14	3.47	3.[illegible]	3.23	3.45	3.27	3.17	3.40	3.26	3.21	3.07	2.97	3.33	3.29	3.26	3.30
August 1[illegible]					3.[illegible]	4.38	3.95	3.85	4.32	4.13	4.06	4.32	4.[illegible]	4.10	3.80	3.[illegible]	3.78	3.[illegible]	3.92	3.82
August 2[illegible]	4.3[illegible]	[illegible].53	[illegible].46	[illegible].5[illegible]	[illegible].07	5.51	4.95	4.93	5.63	5.36	5.15	5.65	5.44	5.44	5.14	5.10	4.71	5.34	5.24	5.08
Sept. [illegible]	3.8[illegible]	[illegible]	4.[illegible]	4.[illegible]	6.63	7.53	6.54	6.78	7.24	7.39	6.97	7.37	7.02	7.11	6.75	6.[illegible]	6.46	7.51	7.04	6.46
Sept. [illegible]	[illegible].04	[illegible].[illegible]5	5.83	5.46	8.33	9.51	8.34	8.55	[illegible].04	9.46	8.56	9.29	8.48	9.09	8.42	8.49	8.14	9.7[illegible]	8.68	8.36
Oct. 8	4.7[illegible]	4.[illegible]2	[illegible]	7.25	11.78	13.89	11.83	1[illegible].12	13.09	13.26	12.49	12.92	11.90	13.03	11.12	11.22	11.75	13.94	12.14	11.59

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TABLE 17

STEELHEAD TROUT AVERAGE WEIGHT IN GRAMS
FINAL CONDITIONS

Type of Water	Effluent		Refrigerated Effluent		1:3		1:50		1:10		1:250		1:500		1:1000		River Water			
Lot Nos.	1A	2	3B	4	5A	6A	9A	10A	7A	8A	11	12	13	14	15	16	17	18	19	20
Oct. 8	4.79	N		N	11.78	13.89	11.83	12.12	13.09	13.26	12.49	12.92	11.90	13.03	11.12	11.22	11.75	13.94	12.14	11.59
Oct. 22	4.80	O	11.50	O	13.30	17.20	17.02	18.42	16.44	17.96	18.04	16.92	17.70	18.90	15.06	17.04	16.91	17.17	15.71	14.98
Nov. 5	6.00		11.86		17.84	23.63	21.80	23.67	22.08	23.92	23.62	21.98	22.26	23.28	18.59	21.47	20.31	21.72	19.00	19.18
Nov. 19	7.20	F	14.14	F	23.11	30.72	26.14	28.00	27.00	29.90	27.40	26.63	26.00	27.27	21.29	25.51	24.36	26.80	21.98	22.65
Dec. 3	10.44	I	16.28	I	30.00	36.83	31.94	34.79	34.73	38.00	33.70	33.33	32.00	33.27	26.17	31.08	29.09	32.14	26.04	26.09
Dec. 17	13.78	S	19.38	S	34.89	44.66	36.02	38.96	39.61	43.40	36.60	36.12	35.10	35.78	29.57	35.10	33.59	36.00	30.00	29.83
Dec. 31	18.11	H	20.71	H	42.12	50.83	39.06	42.34	43.78	46.94	40.00	39.39	37.75	39.84	32.34	37.65	36.40	39.58	31.98	32.17

TABLE 18

MORTALITIES OF CHINOOK SALMON EGGS INCUBATED IN
VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER

Type of Water	Effluent				Effluent 2nd Series				Refrigerated Effluent				1:3				1:3 2nd Series				1:10			
Lot Nos.	1A	1B	2A	2B	1C	1D	2C	2D	3A	3B	4A	4B	5A	5B	6A	6B	5C	5D	6C	6D	7A	7B	8A	8B
Number of Eggs	997	1031	1029	1010	978	992	939	929	1107	973	1056	1027	901	1012	998	1045	954	986	920	925	1031	1108	1195	1051
Stage "A" No.	991	1015	1028	1007			1		157	237	241	231	706	876	842	911	4	2	1	1	343	339	305	377
Stage "B" No.	5	15	1	3					17	28	28	36	176	121	141	134					41	36	27	49
Stage "C" No.	1	1							32	46	45	55	19	15	10						62	52	39	43
Stage "D" No.						3		3	18	14	9	23			5		1		4		60	61	76	69
Stage "E" No.					15	10	9	15	6	1	4	7					9	19	13	11	23	25	39	27
Stage "F" No.					18	24	25	22	10	4	1	7					4	9	2	3	14	24	16	23
Total Number	997	1031	1029	1010	33	37	35	40	240	330	328	359	901	1012	998	1045	18	30	20	15	543	537	502	588
%	100	100	100	100					21.68	33.96	31.06	34.96	100	100	100	100					52.67	48.47	42.01	55.95

Type of Water	1:50				1:250				1:500				1:1000				RIVER WATER CONTROL							
Lot Nos.	9A	9B	10A	10B	11A	11B	12A	12B	13A	13B	14A	14B	15A	15B	16A	16B	17A	17B	18A	18B	19A	19B	20A	20B
Number of Eggs	977	1036	1000	1083	1071	1056	1095	1024	903	1054	1153	1127	971	1066	1052	1097	1099	1010	1144	1029	1088	1063	1213	1009
Stage "A" No.	249	211	220	245	255	239	151	204	201	223	200	143	111	124	182	184	202	161	153	125	126	129	192	133
Stage "B" No.	36	27	17	32	18	18	12	21	18	28	22	14	8	12	9	9	12	8	11	7	5	10	7	4
Stage "C" No.	32	34	23	29	25	36	24	36	26	33	19	18	12	19	23	29	21	25	26	21	16	12	11	14
Stage "D" No.	25	22	20	22	13	22	12	21	12	12	19	16	12	18	16	21	16	20	21	19	16	8	16	17
Stage "E" No.	16	9	10	9	11	17	10	9	9	13	6	10	8	10	5	8	5	12	9	10	11	5	8	4
Stage "F" No.	6	6	6	12	8	10	9	9	3	6	8	8	8	9	14	5	3	5	5	4	2	7	3	6
Total Number	364	309	296	349	330	342	218	300	269	315	274	209	159	192	249	256	259	231	225	186	176	171	239	178
%	37.26	29.83	29.60	32.23	30.81	32.39	19.91	29.30	29.79	29.89	23.76	18.54	16.37	18.01	23.67	23.37	23.57	22.87	19.67	18.08	16.18	16.08	19.70	17.64

9212 78 0552

TABLE 19

MORTALITIES OF CHINOOK SALMON FRY (SERIES 2) HELD IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER

Type of Water	Effluent		Refrigerated Effluent		1:3		1:10		1:50		1:250		1:500		1:1000		River Water			
Lot Nos.	1r	2r	3	4	5r	6r	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Number of Fish	1885	1779	1472	1345	1794	1812	998	1139	1332	1417	1481	1528	1368	1765	1327	1446	1616	1741	1777	1741
Mortality -----Dec. 5				1			4	1												
Dec. 6-12	35	13		2	7	5	16	22	1	5	4					2	1	3		1
Dec. 13-19	413	244	3	3	2	3	1	1	2	2	1	2	8	5	7	4	7	7	7	6
Dec. 20-26	31	50	41	18	20	17	5	5	2	3	6	2	2	7	1	3	6	5	3	5
Dec. 21-Jan.2	170	121	23	2	67	196	17	26	7	5	7	3	6	1	2	1	1	2	1	3
Jan. 3-9	650	490	3	3	187	312	8	14	5	2	1		2		1	1				
Jan. 10-16	499	738	9	1	301	402	14	18	4	2	2	4	4	2		2		3	2	1
Jan. 17-23	86	111	32	21	374	282	10	22	2	3	1	3	2	1	3		5	1	2	1
Jan. 24-30	1	12	166	144	346	240	11	11	9	6	4	5	7	4	5	5	7	12	12	11
Jan. 31-Feb. 6	A_{1_1}	A_{1_1}	349	274	328	222	22	21	4	3	4	9	12	5	8	5	6	10	12	21
Feb. 7-13	$D_{e_{a_d}}$	$D_{e_{a_d}}$	741	682	103	94	36	43	6	4	8	2	11	6	8	8	8	7	11	6
Feb. 14-20			91	161	24	16	33	41	3	6	8	7	9	6	2	9	4	9	17	8
Feb. 21-27			12	30	9	13	29	39	6	3	8	11	3	7	3	10	12	5	8	5
Total	1885	1779	1470	1342	1768	1802	206	264	51	44	54	48	66	44	40	50	57	64	75	68
%	100	100	99.86	99.78	98.55	99.45	20.64	23.18	3.83	3.10	3.65	3.14	4.82	2.49	3.01	3.46	3.53	3.68	4.22	3.91

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TABLE 20

MORTALITIES OF CHINOOK SALMON FINGERLINGS (SERIES 2) HELD IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER

Type of Water	Effluent		Refrigerated Effluent		1:3		1:10		1:50		1:250		1:500		1:1000		River Water			
Lot Nos.	1S	2S	3S	4S	5S	6S	7	8	9	10	11	12	13	14	15	16	17	18	19	20
No. of Fish	494	487	491	481	479	490	481	472	496	492	493	501	492	497	498	495	492	496	496	498
Feb. 28-Mar. 6	3	3		4	1	4	8	12	3		1		3	1	1	1	3	2		
Mar. 7-13	5	3		3	2		10	14	2	1	3		1		2	2		1		
Mar. 14-20	4	3	3	6		3	11	12		1	4			1		2		3		1
Mar. 21-27	97	31	3	3		5	7	10		1		1		1	1					1
Mar. 28- Apr. 3	192	72	13	2	3	7	9	6		1	2					2		1		
Apr. 4-10	75	77	20	10	3	23	3	8		1			1			1	2	2	3	
Apr. 11-17	15	34	23	23	13	31	12	2	2		1		1		2	1		1	1	2
Apr. 18-24	34	61	51	78	33	34	13	13	2			1	1		1				2	3
Apr. 25-May 1	19	51	60	63	70	59	27	22		3	3		2			1		1	2	
May 2 - 8	17	58	95	67	96	83	27	34	3		1	1	1	4	2			2	2	1
May 9 - 15	9	24	55	35	47	30	24	35	2	5	2	2	1	1	1	1	4		1	1
May 16 - 22	1	7	62	57	29	17	14	35	3		1	1	2	1	3	1	5		1	3
May 23 - 29	6	20	35	31	11	15	18	31	9	8	1	3		2	3		4		3	2
May 30- June 5	8	16	30	46	15	16	23	41	8	7	4	3	3	6	2	1	5	2	5	4
June 6 - 12	4	10	24	33	22	15	21	26	4	5	1	2	5	6		4	5	6	4	10
June 13-19		3	3	4	24	12	11	10	7	3	3	7	3	2		3	7	5	11	13
June 20-26	3	6	2	3	65	59	22	11	11	4	6	6	4	4	6	4	10	9	17	6
June 27-July 3	1	1	1	4	13	33	9	8	5	4	1	3	3		2	3	1		7	3
Total	493	480	480	472	447	446	269	330	61	44	34	30	31	29	26	27	46	35	59	50
%	99.80	98.56	97.76	98.13	93.32	91.02	55.93	69.92	12.30	8.94	6.90	5.99	6.30	5.84	5.22	5.45	9.35	7.06	11.90	10.04

TABLE 21

LENGTH FREQUENCIES OF CHINOOK SALMON (SERIES 2) HELD
IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER
JANUARY 30 - 31, 1946

Type of Water	Effluent		Refrigerated Effluent		1:3		1:10		1:50		1:250		1:500		1:1000		River Water			
Lot Nos.	1r	2r	3	4	5r	6r	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Length - m.m. 28			4																	
29			8	5	6															
30	N	N	27	15	13	10		1				1					1		1	
31	O	O	9	23	19	21			1	1	1			1	1	1	1			1
32			2	6	10	17	3	5	5	1	5	5	9	6	12	5	10	8	5	5
33	F	F		1	2	2	12	8	18	9	15	19	17	18	17	17	20	14	19	13
34	I	I					7	9	18	23	21	19	15	13	17	19	15	23	19	20
35	S	S					13	12	6	11	8	6	7	10	3	7	2	5	4	10
36	H	H					10	11	2	4			2	2		1	1		2	1
37							4	4		1										
38																				
39							1													

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TABLE 22

LENGTH FREQUENCIES OF CHINOOK SALMON (SERIES 2) HELD
IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER
FEBRUARY 26, 1946

Type of Water	Effluent		Refrigerated Effluent		1:3		1:10		1:50		1:250		1:500		1:1000		River Water			
Lot Nos.	1r	2r	3	4	5r &	6r	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Length m.m. 30			3	1	4	1														
31				2	8	6														
32	N	N		4	9	6	2	1												
33	O	O		3	4	2	2	5		1					1					
34			1		1		2	7	1		2	1			1			1	1	1
35	F	F					4	5	4	4	4	3	2	6	2	5	4	11	5	5
36	I	I					6	9	4	10	6	12	17	16	16	12	10	13	12	7
37	S	S					7	5	8	16	14	16	17	14	18	16	16	14	20	22
38	H	H					7	6	11	10	21	12	7	8	11	11	14	8	9	11
39							8	6	14	5	3	6	6	5	1	3	5	3	2	4
40							9	4	8	4			1	1		3	1		1	
41							3	2												

TABLE 23

LENGTH FREQUENCIES OF CHINOOK SALMON (SERIES 2) HELD
IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER
MARCH 27, 1946

Type of Water	Effluent		Refrigerated Effluent		1:3		1:10		1:50		1:250		1:500		1:1000		River Water			
Lot Nos.	1S	2S	3S	4S	5S	6S	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Length in m.m. 32								2												
33			1				2	6												
34			2	1			3	7												
35		1	2	2			5	4		1										
36	2	1	10	5	1		2	5										1	1	
37	8	3	9	11	4	2		3			1	3	1	1			1	2	2	5
38	14	12	11	11	12	11	3	3	3	2	2	6	2	6	2	3	4	2	4	8
39	10	12	8	15	3	10	3	5	5	2	3	8	6	5	3	6	7	9	9	7
40	9	10	5	4	10	10	4	3	10	7	16	13	10	16	10	9	12	8	13	12
41	5	8	2		5	9	6	2	12	15	5	12	9	12	18	14	10	13	8	8
42	1	3		1	9	5	7	2	12	11	12	6	11	7	10	9	9	8	9	4
43	1				6	2	4	3	4	9	8	1	7	3	6	5	7	6	3	5
44							4	3	4	3	3	1	4		1	3			1	1
45						1	3	1								1		1		
46							2													
47																				
48							1	1												
49							1													

TABLE 24

LENGTH FREQUENCIES OF CHINOOK SALMON (SERIES 2) HELD IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER
APRIL 25, 1946

Type of Water	Effluent		Refrigerated Effluent		1:3		1:10		1:50		1:250		1:500		1:1000		River Water			
Lot Nos.	1S	2S	3S	4S	5S	6S	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Length in m.m. 35								2												
36				2	1		3	2			1									
37	3	2	8	3		1		7												
38	4	3	12	11	5	6		4	2			1								
39	6	4	12	11	7	5	4	4	1				1						1	
40	9	9	10	11	4	7	3	2	1		2	2	1	1			1	1	2	
41	8	11	5	7	8	6	2	2		2	2	5	1	1	1	1	6	2	3	
42	11	7	2	4	2	10	3	3	2	3	3	8	5	2	6	5	5	5	7	7
43	6	7	1	1	5	5	3	2	4	5	10	7	8	10	3	8	4	6	7	8
44	3	4			6	4	4	3	7	5	9	5	6	8	5	4	6	8	8	8
45		2			6	3	1	3	6	7	9	5	7	11	10	11	8	9	9	8
46		1			3	2	5	4	8	12	5	6	8	10	5	7	8	4	4	4
47					1		6	3	7	7	5	7	11	3	10	7	6	4	4	3
48					1	1	6	3	7	2	2	3	1	2	6	4	1	5	3	6
49							3	2		5	1	1	1		1	2	4	4	1	3
50							4	1	3	2	1			2	2	1	1	2	1	1
51							2		2						1					2
52					1			2												
53																				
54								1												
55																				
56																				
57							1													

TABLE 25

LENGTH FREQUENCIES OF CHINOOK SALMON (SERIES 2) HELD IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER MAY 22, 1946

Type of Water	Effluent		Refrigerated Effluent		1:3		1:10		1:50		1:250		1:500		1:1000		River Water			
Lot Nos.	1S	2S	3S	4S	5S	6S	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Length in m.m. 35			3	2			1	3												
40	14	23	40	38	10	15	7	9	1											
45	6	27	7	10	23	26	8	13	1	2	1	1	2	3	3	3	5	3	4	1
50					14	8	11	16	19	18	19	25	21	28	21	17	24	8	27	14
55					1	1	10	7	20	27	25	21	21	19	16	25	16	23	18	28
60					1		8	2	9	2	5	3	6		10	5	5	12	1	6
65					1		4			1								4		1
70							1													

TABLE 26

LENGTH FREQUENCIES OF CHINOOK SALMON (SERIES 2) HELD
IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER
JUNE 19, 1946

Type of Water	Effluent		Refrigerated Effluent		1:3		1:10		1:50		1:250		1:500		1:1000		River Water			
Lot Nos.	1S	2S	3S	4S	5S	6S	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Length in m.m. 40	3		6	4	2	8	2	1												
45	2	10	7	11	19	18	5	6												
50	1	4	1	1	13	9	8	6	3			1					2		1	2
55			1		9	3	7	5	5	5	8	7	7	6	1	6	2	2	11	5
60					5	7	5	3	13	10	12	13	10	17	16	8	18	13	22	11
65					2	3	6	7	8	15	21	18	16	19	15	18	13	20	8	18
70						1	5	7	12	14	4	6	6	6	13	10	9	8	7	9
75							4	11	6	3	5	4	8	2	3	6	4	6	1	4
80							5	1	3	2		1	3		2	2	2			1
85							2	2		1								1		
90							1													
95						1		1												

9 2 1 2 5 7 3 ? 5 5 0

TABLE 27

LENGTH FREQUENCIES OF CHINOOK SALMON FINGERLINGS (SERIES 2)
HELD IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER
JULY 3, 1946

Type of Water	Effluent		Refrigerated Effluent		1:3		1:10		1:50		1:250		1:500		1:1000		River Water			
Lot Nos.	1S	2S	3S	4S	5S	6S	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Length in m.m. 35			1																	
40	1		3	1			1	1												
45		3	4	5		4	1		1											
50		2	2	2	3	3	4	6	1										1	
55		1		1	9	7	5	3	1	3	1		1	2			1	1	6	4
60		1			7	13	4	2	6	7	5	6	5	6	6	3	7	5	12	3
65			1		9	10	11	6	8	12	10	10	17	11	15	4	6	10	17	5
70					1	2	8	7	14	9	13	12	9	13	10	15	20	12	8	11
75					3	1	5	4	10	9	8	8	8	5	12	11	4	7	2	15
80							1	5	2	2	5	6	7	7	3	8	8	6	2	7
85						2	5	7	4	5	6	6	2	3	4	7	3	8	2	4
90							3	5	3	2	2	2	1	3		2	1	1		1
95							1	2		1										
100								1												
105							1	1												
110						1														

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9 2 1 2 5 7 8 0 5 6 1

TABLE 28

AVERAGE WEIGHT IN GRAMS OF CHINOOK SALMON (SERIES 2) HELD IN VARIOUS CONCENTRATIONS OF AREA EFFLUENT WATER

Type of Water	Effluent		Refrig. Eff.		Refrig. Eff.		1:3		1:3		1:10		1:50		1:250		1:500		1:1000		River Water			
Lot Nos.	1S	2S	3	4	3S	4S	5R	6R	5S	6S	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1/30/46			.43	.44			.41	.38			.50	.47	.52	.53	.53	.52	.53	.53	.52	.52	.50	.49	.50	.52
2/13			.46	.45			.43	.39			.57	.53	.60	.60	.57	.59	.59	.60	.57	.63	.58	.55	.57	.59
2/27	.66	.68	.40	.45	.67	.65	.31	.38	.64	.64	.59	.55	.68	.67	.67	.68	.67	.66	.65	.70	.67	.63	.64	.68
3/13	.76	.75			.70	.69	.50	.50	.84	.80	.66	.60	.81	.82	.84	.76	.83	.81	.81	.82	.82	.80	.76	.82
3/27	.74	.73			.68	.72			.87	.84	.71	.64	.96	1.00	.95	.93	.96	.95	.96	.98	.97	.98	.93	.93
4/10	.79	.82			.69	.74			.94	.91	.90	.85	1.18	1.15	1.11	1.07	1.11	1.08	1.12	1.14	1.08	1.11	1.02	1.07
4/25	.88	.82			.74	.74			.91	.88	1.02	.92	1.22	1.25	1.18	1.12	1.12	1.13	1.20	1.22	1.16	1.27	1.16	1.30
5/8	.93	.88			.67	.72			.98	.97	1.14	1.02	1.54	1.54	1.48	1.44	1.44	1.38	1.50	1.49	1.43	1.61	1.37	1.58
5/22	1.00	.96			.76	.81			1.26	1.21	1.73	1.46	2.07	2.07	2.12	2.06	2.12	1.96	2.13	2.18	2.07	2.36	1.95	2.22
6/5	1.27	1.27			.75	.79			1.50	1.50	2.66	2.10	2.83	2.86	2.88	2.81	2.78	2.64	2.80	3.00	2.78	3.22	2.52	2.95
6/19	1.50	1.43			1.13	1.25			1.94	1.96	3.93	3.21	3.82	3.76	3.77	3.73	3.73	3.54	3.66	4.03	3.58	3.98	3.09	3.71
7/3	1.00	1.71			1.27	1.11			3.00	3.43	5.57	4.89	5.26	5.26	5.14	5.10	5.20	4.65	5.07	5.00	4.59	4.99	4.06	4.68